THEORY OF RELAYS

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1. GENERAL

(A) Introduction

1.01 This section covers general information on relay structure and design. It is reissued to provide additional information on relays of recent development.

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1.02 The data contained herein is purely of a descriptive nature and, while particular types of apparatus are discussed, only such items that are of a general nature are covered.

(B) Dating of Relays

1.03 Relays of the Step-by-Step and the U and Y types have the date of manufacture stamped on the heel piece or spool head respectively. The date stamping shows three, two, one or no horizontal bars together with the last two digits of the year to designate the first, second, third or fourth quarter of that year, respectively. Thus a relay with the numerals 50 and three horizontal bars (50≡) indicates that the relay was manufactured in the first quarter of 1950.

(C) Abbreviated Designations

1.04 The following list shows the various designations together with their respective descriptions:

A-C - Alternating Current

D - Differential

DB - Double Biased - Biased in both directions

DP - Dashpot

EP - Electrically Polarized

FO - Fast Operate

FR - Fast Release

MG - Marginal

NB - No Bias

NR - Non-Reactive (To voice frequency)

P - Magnetically polarized using biasing spring or having magnetic bias

S & M - On polarized relays used in telegraph circuits to indicate the "spacing" and "marking" contacts, respectively

SA - Slow Acting

SI - Series Inductance

SO - Slow Operate

SR - Slow Release

TS - Two Step

(D) Relay Designations

1.05 The various types of relays are designated by either a letter or a number, such as E type and 114 type. The individual relays are designated (or coded) by adding a number or letter to the type designation, such as E-156 and 114-AK relays. This code mark, thus distinguishes a relay of a certain type, having definite windings and contact spring arrangements.

2. MECHANICAL AND ELECTRICAL FEATURES

(A) General

2.01 A relay is fundamentally an electrically operated switch which can open or close contacts when suitable electrical conditions are met. It consists of an electromagnet (core and winding), an armature and contacts. These parts are arranged in such a way that when the core becomes magnetized by an electric current through the winding or windings, the armature is attracted by the core or pole pieces and moves sufficiently to open or close the contacts.

2.02 When the circuit through the relay winding is closed, the core becomes magnetized and sets up magnetic flux in the magnetic circuit. One end of the magnetized core becomes a north pole and the other a south pole; and if the direction of current through the winding is changed, the polarity of the core is reversed. When the current is in such a direction as to make the end of the core nearest the air gap a north pole, the lines of force or flux go out of the core, across the gap and into the armature, thence through the return pole piece to the other end of the core, thus completing the magnetic circuit. With the end of the core nearest the air gap a north pole, the end of the armature facing it becomes a south pole, because it is the other end of a magnet. Since unlike poles

attract each other, the armature will be drawn toward the core if the flux produced by the current through the winding is great enough.

2.03 Relays can be divided into two broad classes, namely general-purpose relays and special-purpose relays. Most telephone circuits are composed of general-purpose relays. The general purpose relay is usually a direct current relay operating in a voltage range of a few volts to approximately one hundred volts. The most common voltages are 24 and 48 volts. Many spring combinations and a variety of winding combinations are used to meet various operating conditions. The contacts usually carry small currents, primarily for the purpose of operating other relays. The acting times of these relays range from a few milliseconds to several hundred milliseconds.

2.04 The special purpose relay is usually designated for a particular type of application. Among its characteristics may be high speed, extreme sensitivity, polarized operation, alternating current operation or contacts with heavy load carrying capacity.

(B) Core and Armature

2.05 The material which is generally used for the manufacture of relay cores and armatures is Magnetic Iron, a soft grade of iron. Another material, Silicon Steel, is used mainly for relays required to operate on a small energy input, such as supervisory relays (B type) and for alternating current relays. Another material, a special nickel steel alloy called Permalloy developed by the Bell Telephone Laboratories, is used for highly sensitive relays of the 209, 228 and 239 Type. Permalloy is also used for certain relays of the B, R, S and U Types to improve their margin of operation. To prevent rust, relay cores and armatures are given a protective finish of either zinc, nickel or chromium.

2.06 The design of the magnetic structure of a relay - that is, the core and armature - is based mainly upon the pull the armature must exert in order to move a certain load a certain distance. The flux necessary to produce this pull is dependent upon certain fundamental constants of design which are the leakage flux, the flux density of the core and the flux density of the pole face. Results obtained from tests conducted on a number of different designs and at various loads indicate that the leakage flux depends almost entirely upon the armature air gap reluctance and the ratio of the core length to the core diameter. Curves showing this relation have been prepared and are used in the design of the magnetic structure of various relays.

2.07 The flux density of the core and that of the pole face depend, of course, largely upon the requirements of the relay, but are chosen with respect to first cost and efficiency of operation. The most efficient core design is obtained by using a core flux density corresponding to the maximum permeability of the core iron. Where a relay is required to operate only on short intervals of time, resulting in low annual power charges, efficiency of operation may, however, be sacrificed in order to obtain a low first cost. In this case a core of small cross-section is used, which in turn requires a high core flux density and pole face density in order to obtain the necessary pull. The same consideration applies to relays carrying a very large mechanical load, where the size of the core would have to be made unreasonably large in order to obtain a high efficiency. A core of comparatively small cross-section is, therefore, also used for relays of this type. However, in the case of relays carrying a very light load - for example, five grams - the size of the core may have to be increased considerably more than is needed magnetically in order to give the required mechanical strength for winding and mounting. This results in the use of a core flux density much less than its most efficient point on the magnetization curve. In general, where small forces are involved, a high efficiency of operation is desirable, whereas in designs for the heavier forces more consideration is given to a low first cost.

2.08 The best flux density and area for the pole face with respect to electro-mechanical efficiency is obtained by making the reluctance of the air gap equal to the reluctance of the remainder of the magnetic circuit. This, however, is not always practical, as it may lead to very small armature movements and, consequently, low pole flux densities are generally chosen.

2.09 From the above consideration it follows that for relays carrying the heavier loads, magnetic irons capable of high flux densities are desirable, as the high densities permit a small core section and consequently a small and low cost magnet. Magnetic Iron is, therefore, used for the core and armature of most types of relays. Relays controlling light loads are best constructed from magnetic materials which have a high permeability and low coercive force. A high permeability reduces the energy required to saturate the core and a low coercive force is necessary to prevent the armature from sticking to the core. The magnetic materials used in this case are Silicon Steel and Permalloy, the latter having the better characteristics of the two materials.

(C) Windings

2.10 There may be from one to five windings on a relay. For purposes of differentiation, windings are classified as Primary, Secondary, Tertiary, Quaternary, or Quinary. At least one winding on every relay must be an inductive winding. An inductive winding is wound in such a manner that the current will always flow around the core in the same direction and thus cause the core to become magnetized. A non-inductive winding is wound so that the current will flow around the core in one direction through half of the winding and in the opposite direction through the other half of the winding, thus neutralizing the inductive effect. The term "differential relay" is sometimes used and refers to a relay having two inductive windings of the same number of turns and resistance, connected so that the inductive effect of one winding neutralizes that of the other. Thus, relays equipped with differential windings may be operated by energizing one winding and then released by energizing the other winding.

2.11 A parallel wound relay has two or more identical conductors lying parallel to each other and wound at the same time. The result will be a coil of two or more windings each of which will have the same electrical characteristics when subjected to an equal current flow. Fig. 1 is an illustration of the various types of windings. The designations P1, P2, P3, etc., are usually used to indicate the windings instead of P, S, and T for parallel wound cores. The semi-circular dot on the winding symbol indicates the inner end, or the end of the winding closest to the core.

2.12 Annealed copper wire, ranging in size from No. 20 to No. 40 B & S gauge and having, as insulation, a covering either of black enamel, one or two layers of silk, or a combination of enamel and silk, is used for the inductive windings. The material ordinarily used for non-inductive windings is enamel or silk covered nickel-silver wire, as the high resistance saves winding space.

2.13 Relay spools are generally insulated to withstand a test of 500 volts, 60 cycles, applied between the winding and the core. The material used as a covering for the core and between windings is generally cellulose acetate sheet which is also effective in preventing deterioration of the smaller sizes of copper wire from corrosion. This corrosion is usually an electrolytic action between different windings and winding and core, caused by moisture in the winding and the potential on the winding and the core. In addition to this insulation on apparatus using multiple-wound (or filled) coils, such as U and Y type relays, a thin piece of cellulose acetate sheet is used between each layer of winding. Multiple-wound coils are made by winding a number of coils of the same kind on a single arbor with slight separations between adjacent windings so that the coils may be cut apart when completed. Where this method is used, the insulation of the wire is generally extra thin enamel.

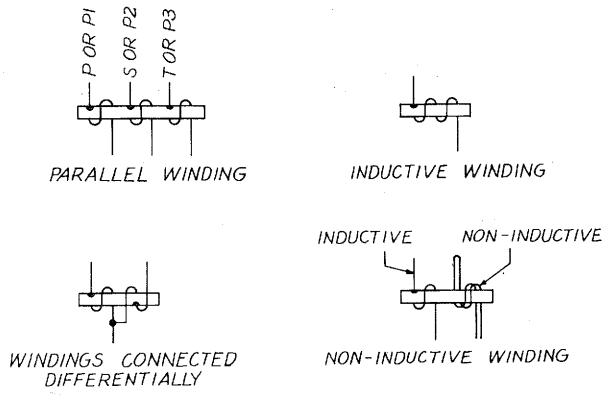

Fig. 1 - Relay Windings

2.14 To prevent abrasion, the coil is provided with a covering of bleached muslin impregnated with a resin compound and faced on both sides with cellulose acetate. This covering, greenish in color, is known as Vincellatate muslin.

2.15 Spoolheads are generally constructed of phenol fibre although sometimes a metallic spoolhead is used for mechanical reasons; for example, on the 206 type relay. The lead-out wires of the winding are insulated and separated from each other by means of end washers of either varnished red rope paper or cellulose acetate sheet, and are brought out to terminals in the spring pile-up, or terminals fastened to the rear spoolhead.

2.16 The design of a suitable winding depends, of course, largely upon the force of ampere turns required for operating the particular arrangements of springs involved. A number of different factors must be considered, however, in determining the proper winding and spool dimensions, which are briefly covered in the following paragraph.

2.17 The maximum number of ampere turns that can be safely applied to a relay winding is determined by the maximum permissible temperature rise in the winding. This rise in temperature is dependent upon the circuit conditions and upon the heat dissipating capabilities of the winding and relay structure. For the proper dimensions of the spool, first cost and efficiency of operation are the deciding factors. The volume of wire used in the spool determines its first cost, while a variation in the length of the coil, which changes its leakage flux, determines the efficiency of the coil. In general, a short thick spool is the most efficient but is high in cost, while a long thin spool is cheap in first cost but not as efficient. For the accurate determination of the number of turns of wire that may be wound on a spool, winding formulae have been developed. These winding formulae are used in connection with winding constants, which have been determined for various sizes of wire and kinds of insulation, and take into account all the variables involved in actual winding practice.

(D) Contacts

2.18 The selection of the proper contact material is important, as in most cases the useful life of a relay is determined by the life of its contacts. The contact material used must be practically free from corrosion, as corrosion acts like a high resistance film on the contact surface. Contacts must also be able to withstand the electrical wear caused by arcing, and must be sufficiently hard to limit the mechanical wearing to a minimum.

2.19 Relay contacts are made from No. 1 contact metal (an alloy of platinum, gold and silver), No. 2 contact metal (palladium), platinum, tungsten or from special contact materials in instances of severe operating conditions such as are encountered with 209 type relays. In general, the "U", "Y" and multi-contact relays for the crossbar system employ twin contacts of silver, except in talking circuits where no current is made or broken. In these cases twin contacts of palladium are used. The size and shape of contacts depends largely upon the mechanical wear to which they are subjected and upon the energy to be controlled. The size is also made sufficient to take care of manufacturing variations in the location and alignment of the contacts. This is accomplished by mating a point contact with a disc contact. The point is required to make within the circumference of the disc. Thus the amount of permissible variation in alignment depends upon the diameter of the disc. Because of greater economy in the use of precious metal, a contact pair consisting of two bars meeting at right angles is now being used and is expected to largely replace the point-disc pair. In this design the amount of permissible variation in alignment depends upon the length of the bars

2.20 The sizes and shapes of relay contacts most widely used are shown in Fig. 2. Contacts are usually attached by spot welding to the contact members, except in the case of contact screws where they are tightly fitted.

2.21 In order to prolong the life of contacts, contact protection circuits are used in a number of instances. They are for the purpose of limiting the arcing at the contacts and consist in most cases of either a non-inductive shunt across the winding, or a non-inductive resistance in series with capacity across the winding or contacts. Another arrangement consisting of non-inductive resistance in series with

capacity and the capacity again shunted by a non-inductive resistance is used for conditions such as are encountered by the contacts of the 209 type relay employed in telegraph circuits.

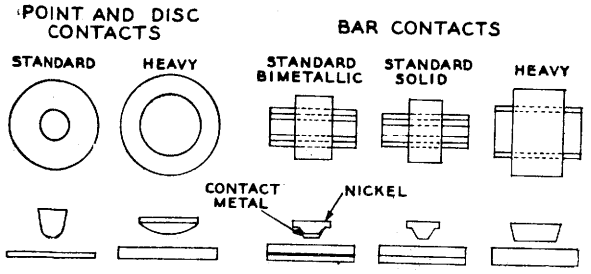

Fig. 2 - Relay Contacts

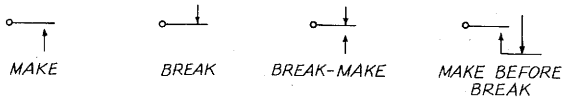

Fig. 3 - Spring Combinations

(E) Spring Combinations

2.22 There are two basic relay spring combinations known as "make" and "break". Two other common spring combinations are the "transfer" and the "continuity transfer". The transfer normally opens the break contact before closing the make contact. The continuity transfer gives a positive make-before-break contact sequence. These spring combinations are illustrated in Fig. 3.

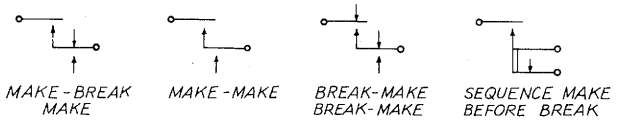

Fig. 4 - Spring Combinations

2.23 Other spring combinations include make-break-make, make-make, break-make-break-make and sequence make preliminary make-before-make. These spring combinations are shown in Fig. 4. There are spring combinations other than the above. However, they are used much less than the types mentioned.

(F) Relay Requirements

2.24 Relays are adjusted to certain mechanical and electrical requirements to insure their operation in the circuit for a reasonable period of time. Although a relay may apparently function satisfactorily in a circuit when it meets its electrical requirements, there is no assurance that its adjustment is permanent unless certain mechanical conditions are met. Since a relay may be considered an electrically operated switch, it is obvious its switching arrangement, that is, the contacts must function properly. Contact alignment and a minimum contact separation are, therefore, necessary. This, however, is not sufficient, as a certain contact pressure is essential to prevent fluttering between the contacts. Spring tension, contact follow and stud gap are the requirements which in conjunction with the electrical requirements insure satisfactory contact closure. In addition, there are a number of other mechanical requirements depending upon the type of relay, such as armature travel, tightness of assembly, clearance between parts, straightness of springs, mounting, etc., which are necessary to insure satisfactory operation.

2.25 The electrical requirements cover operate, non-operate, release and hold conditions and are in the form of current, voltage, or non-inductive resistance values. A soak value is sometimes specified in connection with an operate or release current value. The purpose of this is to produce the maximum amount of residual magnetism that the relay may develop in service, and which would either aid or oppose its operation. In the majority of cases the electrical requirements for a relay consist of an operate and a non-operate value. The non-operate value is mainly for the purpose of insuring back contact pressure and sometimes to meet a non-operating circuit condition. Most E, H, R and U type relays have only an operate value, the non-operate having been replaced by minimum

spring tension requirements on the armature or traveling springs, thus insuring a more uniform back contact pressure adjustment. An operate and a release value are usually required for relays associated with external circuits, such as trunk, line, and supervisory relays, in order to effect the release of the particular relay against a current due to leakage in the circuit. A hold value is sometimes specified to insure that the relay does not release when the current through the relay winding is decreased to less than its operate value or to insure that certain relays remain operated during a series of pulses. One or more of the aforementioned values may be specified for a relay, depending upon the circuit conditions and number of windings.

2.26 In the majority of cases relays are adjusted on a direct current flow basis. Where a relay cannot be conveniently isolated, voltage values are sometimes applied, as this eliminates the necessity of opening the circuit in order to isolate the relay for current flow purposes.

2.27 Relays operating on alternating current are usually adjusted on alternating current by means of non-inductive resistance in series with the relay or be means of the low shunt method.

2.28 The low shunt method of applying alternating current tests to A-C. relays utilizes an arrangement whereby a resistance of relatively low value is bridged across the circuit. The function of this resistance is to lower the impedance to such a degree that the effect of other impedances normally shunting the relay is materially reduced. The normal shunts encountered are the D-C. supervisory relay in the case of cord circuits, and the repeating coil in the case of line circuits. The impedance of these shunts varies from 500 ohms to infinity and in conjunction with the relay alone causes a wide variation in combined impedances. However, when the low shunt is added, it dominates the circuit and variations in other impedances in parallel have little or no effect on the total impedance. Therefore, when a definite current flow is established through the circuit by means of a meter, it results in a definite voltage across the circuit, regardless of the impedance normally shunting the relay. Consequently, the low shunt method of testing relays insures a very uniform and reliable method without resorting to complicated circuit preparation.

(G) Relay Operating Characteristics and Adjustments

2.29 The force which pulls the relay armature to actuate the contact springs is developed by current flowing through the winding. Since the winding is inductive, the initial current does not immediately jump to a value determined by the relay resistance and circuit voltage, but rises at a rate determined by the time constant of the winding and certain other electric and magnetic properties of the structure. Thus, the contacts do not move until the current has risen to a level where the magnetic flux generated across the armature air gap provides sufficient force to overcome the initial back tension of the armature. When the armature starts to move, the back tension increases as the contact springs are flexed to a greater and greater extent. At the same time, the operating force increases as a function both of the continuing rise in current and the decreasing reluctance in the magnetic circuit as the air gap closes. The operating force must increase more rapidly than the armature back tension for the relay to operate completely.

2.30 For a particular type of relay, the force or pull developed across the armature air gap is a function of the product of the current and the number of turns of the winding. This product is generally known as ampere-turns. It can be seen that, for a specific required pull, there must be a balance among the winding turns, the winding resistance, and the voltage level for which the relay is designed.

2.31 When the circuit to the relay winding is opened, current flow ceases rather abruptly, unless the winding is shunted, and the relay starts to release. The decay of magnetic flux is affected by eddy currents in the core, by the magnetic material of the relay, by the residual air gap left when the relay is fully operated, and by any conducting paths encircling the core. All these factors, plus the time for mechanical motion, determine the release time of the relay.

2.32 A set of mechanical adjustments is specified for any relay. These have to do with unoperated armature air gap, residual armature air gap (in some cases), direction and limits of spring tension, contact pressure, etc. As determined by the tolerance range of these mechanical adjust-

ments, there are a set of four basic electrical requirements that can be applied to a relay and which determine its operation in a circuit. These are the operate, hold, non-operate, and release requirements, as defined below. The principal mechanical variable which can be changed to make the relay meet the requirements is the spring tension against the relay armature. The requirements are normally specified in terms of current flow as follows:

(a) Operate Requirement: The current level at which the relay will definitely operate. The current at which the relay can operate may extend well below this level.

(b) Hold Requirement: The level to which the current may be reduced, after the relay has operated, which will insure that the relay remains fully operated.

(c) Non-Operate Requirement: The current level at which an unoperated relay definitely will not operate. The relay may operate at any current level above the non-operate value.

(d) Release Requirement: The level to which the current through an operated relay can be reduced with assurance that the relay will completely return to an unoperated condition.

2.33 Since the same mechanical condition must permit the relay to meet all four electrical requirements, or all that are specified in a particular case, the electrical requirements are necessarily closely interrelated. Setting any one requirement value, such as operate, automatically establishes limits within which the others must fall. If a relay is adjustable, the spring tension is regulated to a compromise value which permits meeting all specified electrical requirements. In practice, however, it is seldom that all four requirements are placed upon a relay. For normal straightforward operation in open and closed circuits, the operate requirement alone may be specified. The others are necessary only to meet marginal conditions, or to hold the relay to special speed requirements.

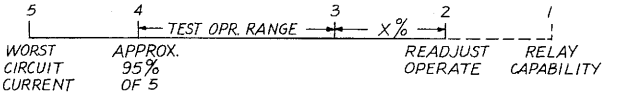

Fig. 5 - Relay Capability

2.34 Relays possess certain minimum theoretical operate current capabilities, shown graphically as point 1 in Fig. 5. From this value, the "readjust operate" value for the circuit requirement table is set at a margin above the capability to permit some ease in adjustment. For circuits which are critical as to relay functions or timing, a test operate value, point 3, is calculated at x% (usually 5%) above the specified readjust value, point 2, to permit a margin for deterioration in the relay. However, where circuit conditions permit, the test operate values have been set at approximately 95% of the worst circuit current which may be encountered in normal operation. This value is shown on the graph at point 4. It is therefore apparent that the test operate value can be set at either of the extremes 3 or 4, or at any intermediate point should circuit conditions warrant it. For ease of adjustment and economy of maintenance in less critical circuits, values at or towards point 4 would be chosen.

(H) Slow Acting Relays

2.35 Slow acting relays, that is, relays which are slow operating, slow releasing, or both, are used in circuit design for various purposes. The principal purposes are to obtain a desired sequence of operation between several relays which are energized or de-energized simultaneously, to secure a definite time interval between the functioning of different parts of a circuit, to secure an automatic momentary circuit, or to prevent momentary disturbances in the relay circuit from affecting the circuit of which the contacts of the relay form a part. A relay is usually made slow acting by one of three methods or by a combination of these methods. The first method is produced electrically by the design of the electrical circuit; the second method

is produced magnetically by the design of the relay winding and the third method is produced mechanically by the design of the relay armature. A brief description of each of these methods if given in 2.36 to 2.45, inclusive.

2.36 The first method is to design or arrange the circuit so that the current through the winding of the relay will build up or die out more slowly than if no means were taken to affect this time. This is usually accomplished by placing an impeance in series with the relay or by shunting the relay with a non-inductive resistance or by a combination of both. Placing an impedance in series with the relay slows down the time of operation of the relay, but does not affect the time of the release. Shunting the relay with a non-inductive resistance, on the other hand, slows down the time of release but has little effect on the time of operation. Slow operation and slow release may be obtained by a combination of the two. The use of an impedance in series with the relay or a non-inductive resistance in parallel with the relay prolongs the time between the closing or opening of the circuit through the winding and movement of the armature. No appreciable effect, however, is produced on the actual speed of movement of the armature. Placing the non-inductive resistance in series with the relay and impedance in parallel with the relay produce the opposite effect, namely, fast operation and fast release. This latter must be taken into account when relays are operated in parallel since if a relay is in parallel with a relay of higher impedance than itself, it will release more quickly when the circuit is broken.

2.37 This method of making a relay slow acting is used very little at the present time. It is necessary to consider its effect, however, in circuit design, as relays are often shunted by non-inductive resistances for the purpose of providing a path around the inductive winding for the passage of alternating or talking currents. Non-inductive resistances are also frequently placed in parallel with a relay to prevent arcing at the contacts through which the relay is operated. The supervisory relays in cord and trunk circuits, which have a non-inductive winding in parallel with the relay winding in order to permit the passage of the voice currents, are an example of the former condition.

2.38 The second method is to design the windings of the relay so that any change in the current of the circuit will produce a greater time interval between the change in the strength of the field or flux in the core than would occur under normal conditions. This is accomplished by the use of an additional short-circuited winding. This winding may be either a regular winding or a single turn of a very low resistance, the latter being the more effective. This single turn takes the form of either a heavy copper head at one end of the core or a copper sleeve over the full length of the core. With this method, as with the first method, no appreciable effect is produced on the actual speed of movement of the armature. This type of construction is used on 149, 162, 178, step-by-step, F, T and Y type relays.

2.39 At the instant the circuit through the winding of these relays is closed, a momentary current is set up in the secondary short-circuited winding by mutual induction. The induced current lasts only as long as the current through the primary or operating winding is increasing, that is, until it has reached its full or steady value. The direction of this induced current is, however, such as to set up a secondary flux which opposes any change in the existing primary or operating flux. This retards the building-up of the operating flux or, which is the same, makes the relay slow acting. For a maximum retarding effect the operating ampere turn requirements should be such that the relay receives just enough current to operate, because in this case the resultant flux does not become strong enough to move the armature, when the circuit is closed, until the effect of the short circuited secondary has been overcome and the flux has reached its full value. The relay will, accordingly, be slow in operation. A relay under such conditions can be made to release comparatively quickly by choosing a design that has a high release requirement, which is accomplished by means of high stop pins or non-freezing discs, in proportion to the operating requirement.

2.40 When the circuit through the relay winding is opened, an action opposite to that described above takes place; that is, the armature does not release immediately because the current induced in the secondary winding, at the instant the circuit is broken, sets up a flux which is in the same direction

as the operating flux, and therefore tends to hold the armature operated. To secure slow releasing, the winding and operating requirements must be so chosen that the final value of the flux produced by the current the relay receives in the circuit is much greater than the releasing requirement. This is accomplished by choosing a relay having a high flux density and a magnetic circuit of low reluctance. The copper sleeve, to obtain a slow releasing effect, is used in some cases for making a relay less responsive to alternating current. This is particularly true in the case of trip relays of the 114 and 198 types.

2.41 The foregoing considerations apply to relays having a copper sleeve over the full length of the core or a copper head at the armature end. The copper head may, however, be located at the heelpiece end of the core, away from the armature. This type of construction is used on some step-by-step relays to obtain a relatively fast operating, yet slow releasing relay and may be explained as follows: At the time of circuit closure, the main flux can leak across the gap between the core and yoke until the retarding effect of the copper head has died down; in addition the reduced electrical inductance allows a faster growth of current in the relay. When the circuit is opened, the coil impedance plays no part, because the current drops to zero immediately. The secondary flux produced by the copper head, however, tends to hold the armature operated, producing the desired slow releasing effect.

2.42 The third method is to design the moving parts or armatures of the relays so that their inertia makes them slow in responding to changes in the magnetizing force. On the 114 and 198 type relays, the inertia is produced by means of a heavy armature. To make the relays slow in operating, the magnetizing force must be great enough to pull up the armature, and for slow release the restoring force, must be as small as will give satisfactory action. This condition may be met by a suitable mechanical design. With this construction, the actual movement of the armature is retarded. Such a design is used for relays to be operated by alternating current, as the inertia of the moving parts prevents the opening of the contacts when the alternating current passes through zero.

2.43 Two or more of the methods outlined above may be used on the same relay, the first and second being the most common combination. It will be seen, therefore, that a relay is not generally intrinsically slow operating or slow releasing, but that these features are determined by a combination of the design of the relay itself and of the circuit in which it is used.

2.44 On the F and T type relays, in addition to winding a few layers of bare copper wire over the core, a slow releasing effect is obtained by magnetic bridge pieces. Magnetic bridge pieces are provided across each hinge gap in order to reduce the reluctance of the magnetic path which is necessary for obtaining a maximum slow releasing effect of the short circuited copper winding. For the same reason the armature is loosely mounted on pins instead of being riveted to a thin, soft iron hinge plate as on other flat type relays. This permits the armature to align itself with the magnetic bridge pieces when the relay is energized. To regulate the time of release, an adjustable stop pin is provided on the F type relay by means of which the operated armature air gap can be increased or decreased, thereby causing, respectively, a faster or slower release. A nickel finish is used because it has better wearing qualities and is thinner than a galvanized finish. A thin finish is a further aid in reducing the reluctance of the magnetic circuit.

2.45 Similar provisions have been made on Y type relays to obtain the desired slow releasing effect. A loosely pivoted armature suspension is also used on this relay together with a hinge bracket which takes the place of the magnetic hinge pieces on F and T type relays. Since the time of release is largely dependent upon the reluctance of the magnetic circuit, embossed surfaces at the armature pole face and the armature pivot points have been provided on Y type relays to insure uniformity of slow releasing characteristics between relays.

3. DIRECT CURRENT RELAYS

(A) A, AB, E, EA, F, H, R, T and 236 Type Relays (Flat Type Relays)

3.01 These relays are known as "Flat Type Relays" because the major

parts of the relay, that is the core, armature and contact springs are punched out from flat stock. See Figs. 6 and 7. This arrangement permits the interchangeability of these parts and results in a decided advantage from the standpoint of assembly and replacement of parts. The punched design has also made possible a reduction in the size of the relay, so that more flat type relays than relays of the other types can be mounted in a given space. Except on the F and T types of relays (which have a loosely hinged armature), a soft iron reed riveted to the ends of the armature and clamped under the spring pile-ups serves as an armature hinge and completes the magnetic return path over the two sides of the armature. In order to reduce the reluctance of the magnetic circuit, thereby increasing the operating capability of the relay, the armature and core have a large pole face area. Magnetic Iron is used for the core and armature of most flat type relays. R type relays using code numbers beginning with R-6000 have Permalloy cores and armatures. The contact springs of flat type relays are made of Nickel-Silver.

In some instances, springs of copper silicon alloy have been used as a substitute material. These are readily distinguished from nickle-silver springs by the dark copper color, although the surface coating may vary somewhat in color.

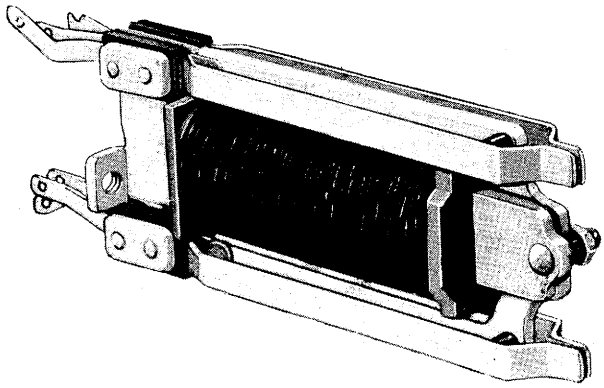

Fig. 6 - "A" Type Relay

3.02 The A type relay, the armature and core of which are made from a thinner stock of iron than that used for other flat types, is used mainly for line and cut-off relays on manual installations. It is also used in isolated cases where a light spring combination is required. This relay is partly superseded by the AB type relay described in one of the following paragraphs.

3.03 The E type relay is a general purpose relay and replaces practically all the barrel type relays of the 122 and similar types. There may be as many as 14 springs (7 in each pile-up) used on an E or R type relay, while not more than three sets, or 9 springs, can be handled conveniently on the spring or barrel type relays (125 type for example). Up to the present time, 59 different spring combinations have been developed for use with E, F, H, R and T type relays, and approximately 2500 E type relays have been coded. Stop pins, or non-freezing discs, are welded to the armature of most E type relays to

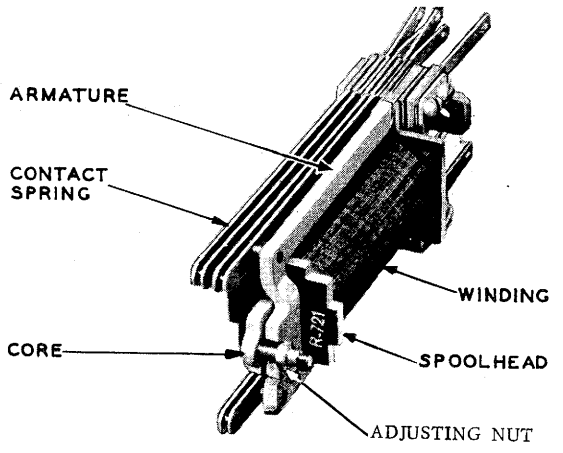

Fig. 7 - "R" Type Relay

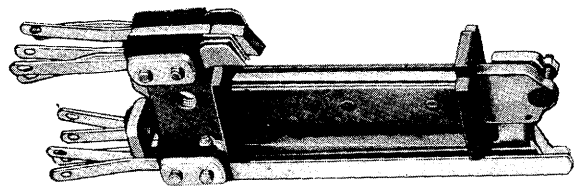

Fig. 8 - Core of "H" Type Relay

prevent the armature from sticking as a result of residual magnetism. The H type relay is practically identical with the E type relay, the only difference being the provision of iron laminations (see Fig. 8) riveted to either side of the core. These laminations give the H type relay a higher impedance at talking current frequencies than the E type possesses.

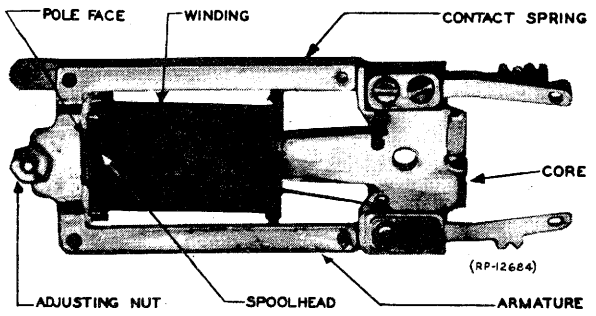

Fig. 9 - EA Type Relay

3.04 The EA type relay is essentially an E type relay modified to permit the use of multiple wound (or filled) coils. The width of the pole face is smaller than that of the E type relay, so that the finished coil may be slipped over the core before the front spoolhead is attached. Some EA type relays, such as the EA2 shown in Figure 9 are equipped with a short coil, since this construction is more advantageous from a manufacturing standpoint. EA type relays are extensively used as line relays in dial equipment.

3.05 The R type relay differs from the E type relay only in the use of a "swaged" core and slightly larger spoolheads. The term "swaged" denotes a pressing operation at the time of manufacture which changes the normally rectangular shape of a flat type relay core (under the winding space only) to an oval shaped core. Although the cross-sectional area remains unchanged, the swaged core affords a greater winding space and a shorter length of turn, because the winding follows more closely the contour of the core than it is possible on a rectangular shaped core. As a result, more turns of a given size wire can be wound on the swaged core of an R type relay than on the rectangular core of an E type relay and still maintain the same resistance. Since this gives the R type relay a decided advantage over the E type, the latter may eventually be entirely replaced by the former.

3.06 The AB type relay resembles the R type relay except that the core and armature are made from much thinner stock. This relay was designed to replace the A type relay and has the advantage of greater stability due to the greater number of turns on the swaged core. The use of straight springs in place of the old type formed springs considerably simplifies the adjustments for spring tension and contact separation.

3.07 The F type relay (see Fig. 10) is a flat, punched type, slow releasing relay. It is of the same general construction as the E type relay, except for the use of magnetic bridge pieces across each hinge gap, a loosely hinged armature, a short circuited copper winding over the core, and adjustable stop pin and a nickel finish. The T type relay differs from the F type only in the use of a swaged core and slightly larger spoolheads and that it has no adjustable stop pin. The advantages of using a swaged core, as pointed out for the R type relay led to the development of the T type relay. Since F and the T type relays are slow releasing relays, they will be considered further under the heading of "Slow Acting Relays."

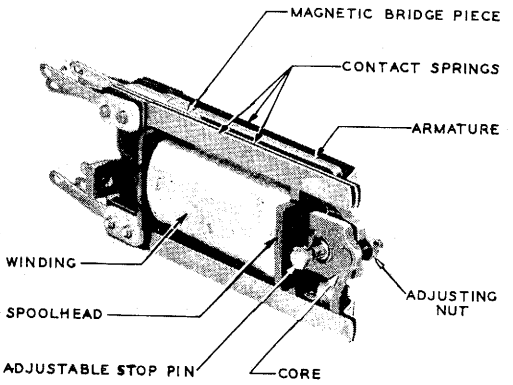

Fig. 10 - "F" Type Relay

3.08 The 236 type relay has the same structure as the E type relay, except that the core of the F type is used in order to obtain the adjustable stop pin feature. In addition to the standard E and F type parts

it is equipped with a thermostat metal spring mounted in place of one of the regular spring combinations. As this is a slow acting relay, it will be considered further under the heading, "Slow Acting Relay".

3.09 Definite mechanical and electrical requirements are specified for the adjustment of flat type relays. The mechanical requirements include armature travel, spring tension, contact separation, contact follow, stud gap, etc., while the electrical requirements in the majority of cases cover only an operate value, the non-operate value having been replaced by minimum spring tension requirements in grams which insure a more uniform adjustment.

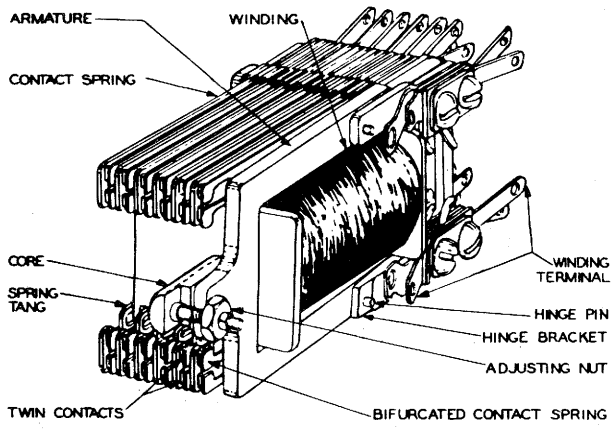

Fig. 11 - "U" Type Relay

(B) U, UA, UB and Y Type Relays

3.10 These relays are general purpose relays similar to flat type relays, but have a round core and are somewhat longer. Other outstanding differences are the use of double or "bifurcated" contact springs, multiple wound (filled) coils and the ability of most of these relays to operate as many as 26 contact springs on one relay, almost twice as many as can be used on an R type relay. This increase in load is made possible by using a larger cross-section of magnetic material in both armature and core and a low reluctance hinge arrangement in the form of a more flexible armature suspension. See Figures 11, 12 and 13.

3.11 Nearly 200 different spring combinations have been provided for these relays, and the design has been so arranged that all contact springs are mounted on one side of the relay while all winding terminals are mounted on the other. This arrangement simplifies the method of bringing out leads in that the primary winding terminals are always nearest the core on the right-hand side of the armature, the secondary winding terminals are next nearest, and the tertiary terminals, when used, are always on the outside. The contact springs, with the exception of certain moving springs on the UB type described in one of the following paragraphs, are tensioned in the same direction (to the right) in the process of adjusting the relay. The moving springs, except on the UB type, are actuated by the pressure of the armature against small insulating studs which are fastened in the springs, and which pass through holes in the stationary springs. This differs from the action on "R" type relays where the studs are fastened to the armature. For uses requiring up to four stationary springs on top and bottom, one size spoolhead has been provided, and a larger spoolhead having more notches is furnished for relays carrying up to the full number of 26 contact springs. The winding terminals project through the pileup toward the front of the relay, and are staggered in position to facilitate application of the connector used when applying electrical requirements to the relay. The core is cylindrical in shape and is molded to the bracket, or in the case of the UA type relay, held in place by means of a screw and two tapered ridges in the core which engage with two slots in the bracket. Where slow operating features are desired provision is made to slip copper or aluminum sleeves over the core. Also for those cases where high voice frequency impedance is desired similar to the needs for which the G and H type relays were made, permalloy shells can be assembled to the relay. These shells consist essentially of a cylindrical permalloy tube, which fits over the relay core. The tube is split in half along its length and is then held in place over the core by means of the coil and spoolhead. Their action is similar to that of laminations. Magnetic iron and permalloy are the magnetic materials used for the cores and armatures of these relays. Relays using code numbers beginning with 6000 are made of permalloy.

3.12 To accommodate the various sizes of spring pileups, three sizes of individual covers are provided. These covers are made of sheet steel and serve both as dustproof covers and for protection against magnetic interference or cross-talk.

3.13 Contact reliability on these types of relays is insured by the use of twin or double contacts and the bifurcating of the operating springs. To illustrate the gains made by the use of twin contacts, it is expected that, if a given single contact relay were to have one failure in 100 operations caused by foreign bodies lodging between contacts, these failures would be reduced to one in 10,000 operations if twin contacts were used. The contact chatter has been greatly reduced compared with flat type relays, chiefly by the use of operating springs which are thin in comparison with the spoolhead springs, a rigid core construction, and a more flexible armature suspension. The reduced contact chatter increases the circuit reliability of the contacts, and also minimizes contact wear.

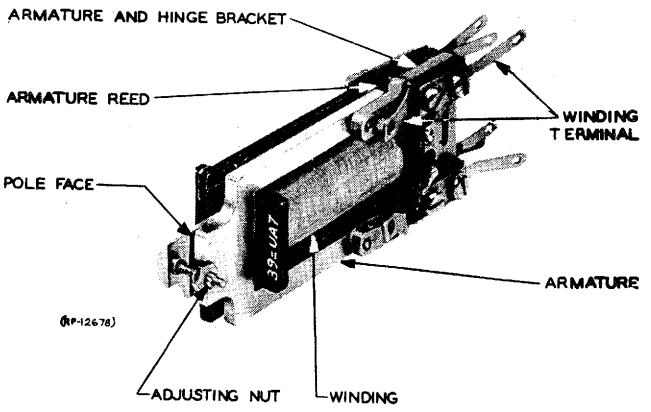

Fig. 12 - "UA" Type Relay

3.14 As illustrated in Figure 12, the principal difference in appearance between the UA and U type relays is that the pole face area of the UA type is much larger. The enlarged pole face area and and the use of a one-piece armature and hinge bracket of thicker material lower the reluctance of the magnetic circuit, thus permitting the relay to operate on less ampere turns than the U type. Since the enlarged pole face requires mounting of the coil before the core is attached to the bracket, the core instead of being welded to the bracket is held in place by means of a screw and two tapered ridges which engage with two slots in the bracket. Other differences are the addition of phosphor bronze armature reeds to hold the armature against its bracket and the use of a smaller diameter core (1/4") and thinner armature (.083") on some UA type relays. The smaller diameter core provides increased winding space and when used with the thinner armature results in a faster releasing relay than the U type. The improved operating characteristics of the UA type as compared with the U type permit magnetic iron UA type relays to be used in place of many permalloy U type relays. For the same reason UA type relays are also used in place of B type relays where sufficient current for operation is available.

3.15 The UB type relay shown in Figure 13 is essentially a U type relay with "card" actuation of the contact springs. The card consists of a piece of insulating material with slots that engage with the tips of the moving springs. It takes the place of the insulating studs used on U type relays and is held in position by two springs which also serve as balancing springs. The card is intended to eliminate changes in adjustment due to stud wear and to reduce the tendency of the contacts to lock. UB type relays are equipped with nickel silver reeds for supporting the armature instead of using the loosely pivoted hinge arrangement of the U type. The reeds are attached to each leg of the armature by rivets located just in front of the ends of the hinge bracket.

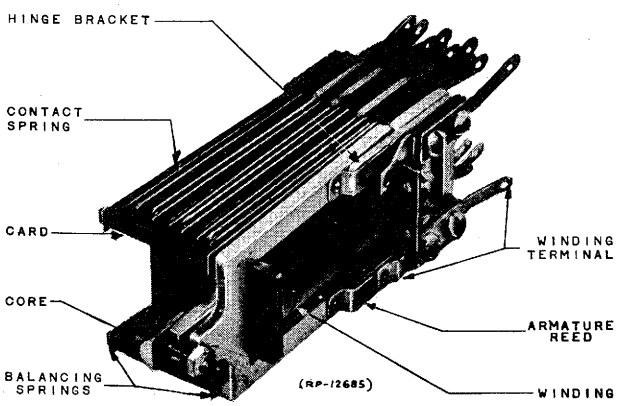

Fig. 13 - "UB" Type Relay

3.16 The Y type relay is a slow-releasing relay capable of replacing previous slow-releasing relays, (149, 162, 178, F and T types), while making available a larger number of contact springs per relay, more reliable contact pressures, and twin contacts. This relay is constructed essentially the same as the U type relay with suitable modifications to afford the desired slow-releasing properties. For the desired time ranges, three sizes of copper sleeves and one size of aluminum sleeve are used.

3.17 The outstanding differences from U type relays are the addition of embossed surfaces on the armature pole face and at the armature pivoting points. These embossed surfaces provide more definitely controlled operated air-gaps, assuring a uniformity of the manufactured product so far as releasing characteristics are concerned. A detailed explanation of the slow operating and slow releasing features in relays is given under the heading of "Slow Acting Relays".

(C) Wire Spring Relays

McBerty North Electric Relay

3.18 The frame of this relay, see Fig. 14, is made of steel alloy and consists of the base plate, one or more cores, and two side plates. All of these parts are precision welded. Corrosion is prevented by a special plating process.

3.19 The coil consists of a plastic spool on which is wound the wire, and is designed so as to easily slip over the fixed core. The relay is designed to operate with small inductive loads thus reducing the arcing problem. This feature reduces contact wear and erosion. The relatively small core required permits compact assembly and reduction of space requirements. The alignment bracket which is of a non-magnetic alloy, locks the coils on their respective cores, and the various other elements of the assembly are held in proper relationship. Each pole piece of steel alloy is slipped over the threaded extension on its particular core and is held in position by the alignment bracket.

3.20 The elements necessary to establish circuit contacts are prefabricated nickel silver alloy structures with precious metal double contact surfaces. These are molded into an integral structure using plastic materials. This entire structure is called the "anvil molding". The individual anvils or the stationary contacts are cut and formed to various lengths as required. The anvil molding is slipped into its proper position and held securely by screws.

3.21 To construct an armature or moving element of the circuit control, a precious metal contact is welded to the tip of a segment of magnetic alloy which in turn is welded to a section of stainless steel wire or reed. Each reed is processed to preclude the possibility of twisting and to insure

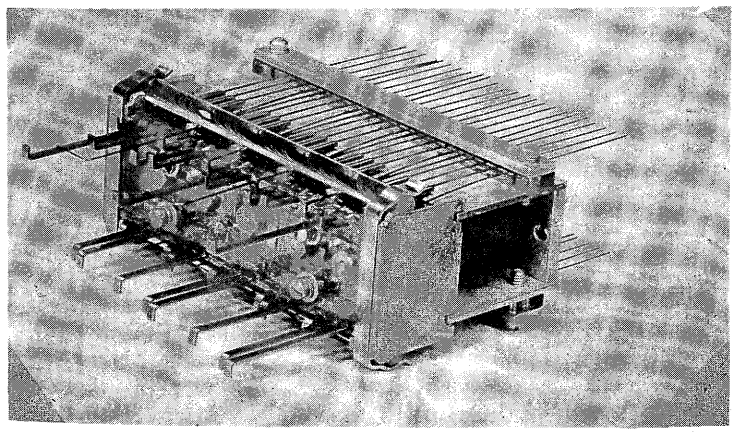

Fig. 14 - (McBerty North Electric Relay)

unrestricted movement when positioned in the final assembly. The necessary number of contact reeds and circuit wiring elements are fabricated into a "reed molding". The reed moldings, one or two on each side of the relay frame, are placed into position and clamped. This places each group of armatures in its magnetic field zone. A pyrex or glass rod on each side of the structure is held in a definite location by the use of clips. These rods function as a protection to the reed armatures and is a means of holding the armatures and their contacts in exact relationship with the anvil or fixed contact numbers.

3.22 On multiple contact relays each of the two reed moldings include 18 armatures with their associated contacts. One molding is mounted on each side of the relay frame. A single coil mounted on the relay frame establishes a common magnetic field which will simultaneously make 36 individual circuit contacts.

3.23 As with other types, these relays may be built to give such properties as normal action, fast action, delayed action and the variables thereof. One form of relay structure has been designed for these general purposes. Coils of various characteristics can be accomplished by the selective use of metallic sleeves over the core with overlay coils. Slow release characteristics can be produced by a copper slug placed on the relay core adjacent to the coil winding.

3.24 This relay finds its major use in MCX type central offices.

AF, AG and AJ Type Relays

3.25 These relays are of recent development and are not in general use as of this writing. They were designed primarily for use in crossbar switching systems. These relays are referred to as wire spring relays, because they are equipped with wires for contact springs. This type relay is cheaper to manufacture and at the same time offers substantial improvements in performance over the existing U and Y types. Wire spring relays are not inter-

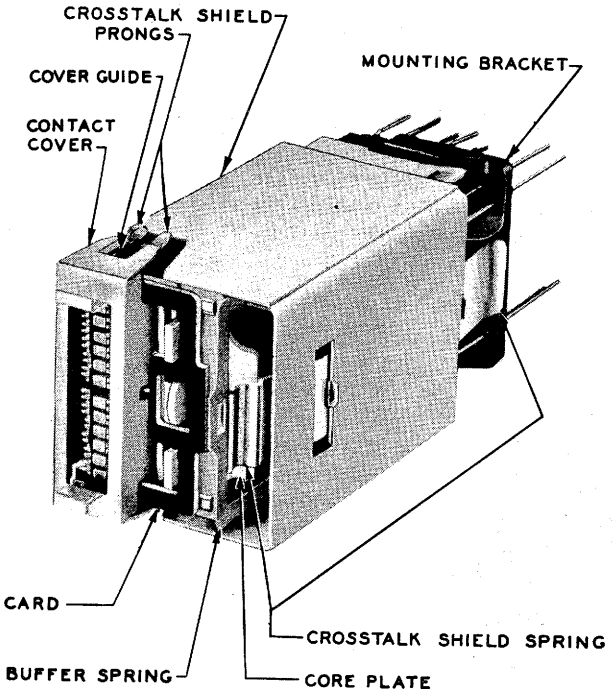

Fig. 15 - Contact Cover and Crosstalk Shield Mounted on AJ-type 12-position Relay

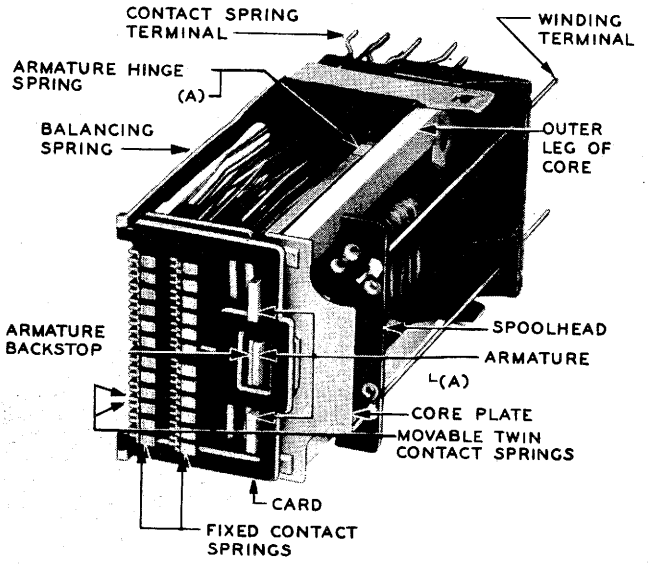

Fig. 16 - General View of AJ-type 24-position Relay - Contact Cover Removed

changeable from a mounting standpoint with U, UA, UB or Y type relays.

3.26 The terminals of these relays are designed initially to be wired with a wrapped soldered connection. A change in the relay terminals being incorporated in the design so that after the inital lot of 128,000 relays, the wired connections will be of the wrapped solderless type. A special tool will be needed to make a connection of the solderless type.

3.27 These relays require less power to operate as a result of the improved magnetic structure, reduced armature travel and lower contact forces as composed to relays of the U type. The wire spring relays come equipped with as many as 24 make contacts or 12 transfer combinations.

3.28 Each relay makes use of an individual contact cover which together with independent twin contacts should greatly reduce the number of open contact troubles.

3.29 AF relays are intended for speed uses and will be used in the major parts of the switching functions. This relay uses an armature with short legs which gives it higher operating speeds and allows it to release with a minimum of armature rebound.

3.30 AG relays are for slow release application. The AG relay uses on armature with long legs and has an embossing or dome which mates with the core center leg. It also uses a sleeve which is mounted over the center legs of the core to obtain slow release. AJ relays Fig. 15 and 16 are basically the same as the AG type. However the AJ type is designed for marginal operation or where a large number of contacts are needed. The armature is equipped with two non-magnetic stop discs. B.S.P. A804.101 gives a more detailed description of these relays.

(D) B and G Type Relays

3.31 B and G type relays are used for supervisory purposes in trunk and cord circuits. Both relays are of the punched type and differ only in the construction of the core and the thickness of the cover used. Fig. 17 shows a B type relay with the cover removed.

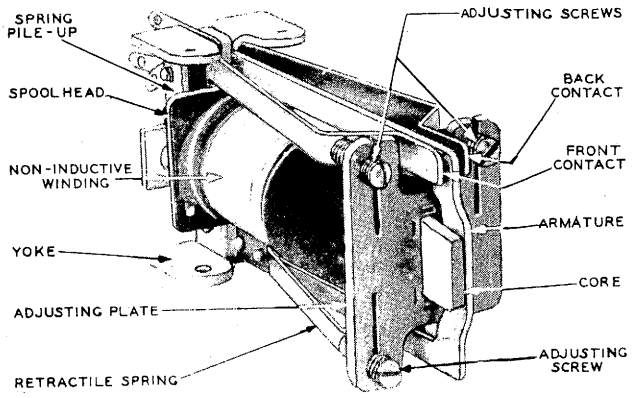

Fig. 17 - "B" Type Relay

3.32 Due to the fact that a B type relay must operate over a wide range of current and yet release when there is still quite some current flowing through its winding, the core of this relay has a very small cross-section. The magnetic saturation point is, therefore, quickly reached and any increase in current through the winding will not materially increase either the flux or the residual magnetism. Since the pull of this relay is necessarily small due to the small cross-sectional area of the core, the armature and core are made from Silicon Steel or Permalloy, which have a higher permeability and lower coercive force than Magnetic Iron. B type relays with code numbers from B-1000 up use Permalloy and have a swaged core. Most B type relays are equipped with one or sometimes two stop pins to guard against sticking due to leakage flux and residual magnetism. Each B type relay is equipped with a soft steel can cover, with removable cap, which is securely held by screws to the yokes of the relay. The purpose of this cover is to protect the relay from dust and to strengthen it.

3.33 The core of the G type relay is of a larger cross-section than that of the B type and has laminations riveted to either side. This results in an increase in impedance at talking current frequencies and thus prevents the talking currents from passing through the winding, which would

cause transmission losses. An individual iron cover with removable cap is also used for this type of relay, but is made of a much heavier stock (approximately 1/16") to prevent transformer action or crosstalk between two adjacent relays in different circuits. Since iron has a much higher permeability than air, the heavy iron cover takes up the stray flux from the relay and acts as a shield against the stray flux from adjacent relays. The principle of shielding against stray flux is illustrated in Fig. 18.

3.34 B and G type relays are adjusted to their mechanical and electrical requirements by means of the three adjusting screws in the adjusting plate, the two upper screws being used for regulating the position of the front and back contact springs or stop springs, while the lower screw is used to regulate the tension on the armature.

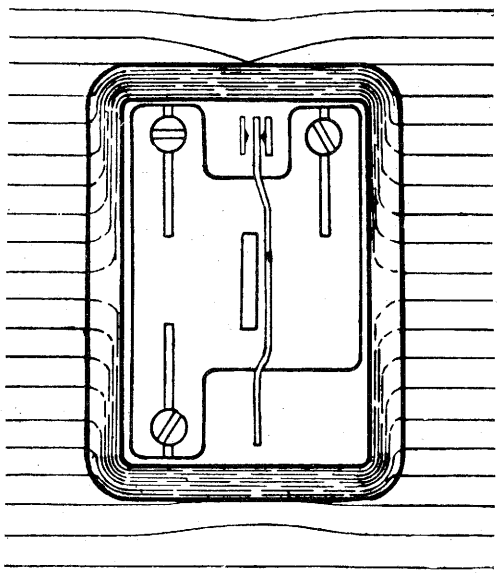

Fig. 18 - Effect of Cover of "G" Type Relay on External Stray Field

(E) Polarized Relays 206, 209, 215, 218-B, 228, 231, 239, 255, 266 and 280 Types

3.35 The term "polarized relays" is used to designate a relay whose armature and core are kept permanently magnetized, usually by means of a permanent magnet. The object of polarizing a relay is to make it respond to currents of a certain polarity only, and to make it more sensitive. These two points are further explained in the following paragraphs.

3.36 The magnetic circuit of the 206, 209 and 215 type relays (see Figs. 19 and 20) resembles that of a Wheatstone Bridge. A permanent horseshoe magnet is mounted around the lower part of the coil of these relays with its ends at the front. Iron yokes (pole pieces) which are attached to the ends of the magnet extend upward in front of the coil and then over the full length of the coil. The armature, which is of the reed type, is rigidly secured at the rear of the relay and is separated from each of the yokes by non-magnetic material.

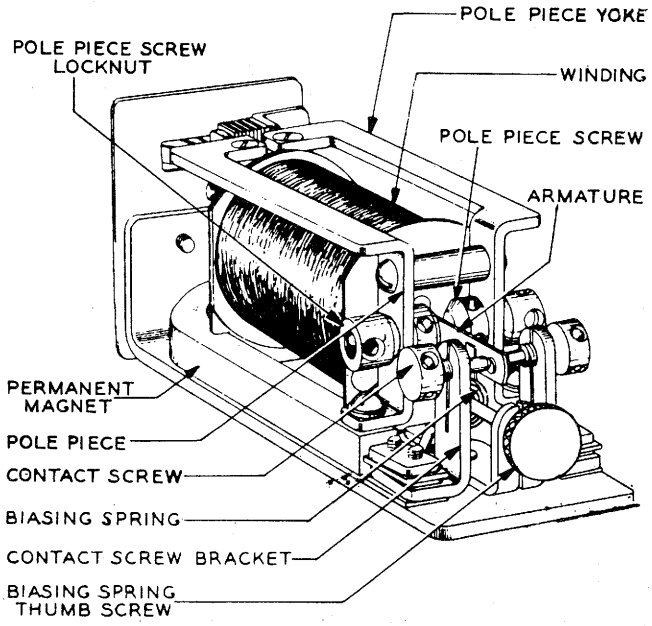

Fig. 19 - 206 Type Relay

The windings are placed over the armature in the form of a single spool, sufficient clearance being provided to allow the armature to move within the spool. The air gap between the armature and either pole piece in front of the coil can be regulated by means of pole piece screws screwed into the pole pieces. The four gaps, that is, the gaps of non-magnetic material between the yokes and the armature at the rear and the two air gaps at the contact

end of the armature, may be considered as the four arms of the Wheatsone Bridge with the armature taking the place of the galvanometer and the permanent magnet that of the battery.

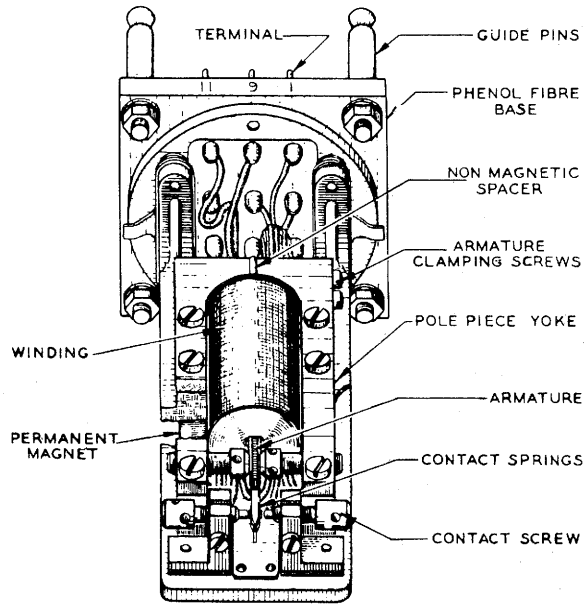

Fig. 20 - 209 Type Relay

3.37 The action of the magnetic circuit of these relays is, briefly, as follows: With the armature in the midway or neutral position, no polarizing flux passes through it, since it connects points of equal magnetic potential. If the armature is moved toward the left pole piece (see Fig. 21), thereby decreasing the air gap on the left and increasing that on the right, some of the polarizing flux will flow from the pole piece on the left (assumed to be a north pole) across the left hand air gap, through the armature, and through the non-magnetic material to the other yoke (assumed to be a south pole). A movement of the armature to the right causes some of the polarizing flux to flow through the armature in the opposite direction; that is from the yoke on the left, through the non-magnetic material to the armature, through the armature,

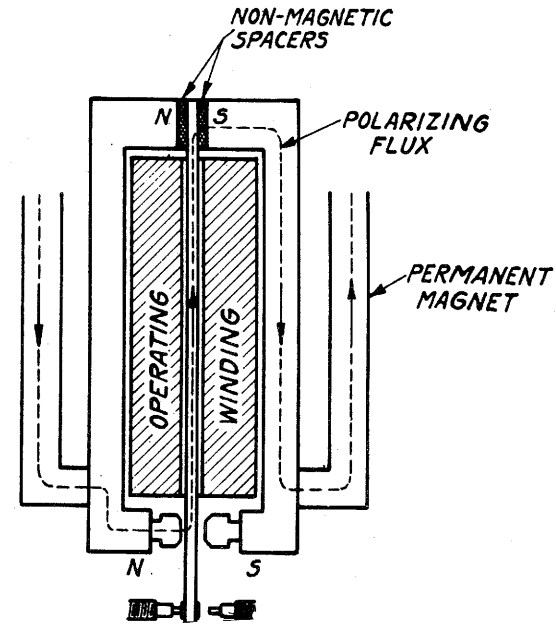

Fig. 21 - Polarizing Flux Through Armature of 206 Type Relay

and across the right hand air gap to the pole piece on the right. The armature being supported in cantilever beam fashion, is resistant to displacement from its midway position in the air gaps due to its natural stiffness which opposes the polarizing force as the armature is displaced. Since the relay can be adjusted by means of the adjustable pole pieces, and contact screws which limit the armature travel, so that the polarizing force is just sufficiently in excess of the opposing force of the armature to hold the armature against either contact screw, the armature is practically in a floating condition and can thus be

controlled by a very small operating current. The application of this operating current causes the free end of the armature to become either a north or a south pole (see Fig. 22), depending upon the direction of the current, and it is drawn toward that pole piece which possesses the opposite polarity. When the relay operates under the influence of reversals of current through its winding, both the operating and polarizing fluxes reverse in direction through the armature. From the foregoing it is evident that the relay armature will operate to either one side or the other, depending upon the polarity of the operating current. Since the polarizing flux aids the operation of the relay armature, less operating flux is required and a polarized relay is therefore, more sensitive than the ordinary neutral relay.

3.38 Front and back contact or stop screws are provided on all of these relays which, in addition to functioning as contacts, also limit the armature travel as stated previously. A biasing spring, pressing lightly against the left side (near the contact end) of the armature, is used on some 206, 231 and 239 type relays. The purpose of this spring is to hold the armature, when unoperated, against the back contact screw. When the biasing spring is not used, the normal position of the armature may be against either the front or back contact screws, or floating between the contacts. In order to effect a longer and better contact closure, certain codes of these relays are equipped with a chatterless armature, that is, an armature which, instead of being solid at its contact end, is provided with two flexible contact springs bearing against each other at the tip. The 209, 215 and 255 type relays have no soldering terminals, their windings and contacts being connected to a terminal block which is fastened to the base plate of the relay. The terminals of the terminal block fit into corresponding terminal springs of the connecting block which is fastened to the relay mounting plate. This arrangement permits easy removal and replacement of the relay for inspection and adjustment.

3.39 The 255 type relay shown in Fig. 23 was designed primarily for telegraph service. While structually similar to the 215 type, its more rigid construction provides for added stability in operation. This is obtained by providing the relay with a knurled tension nut and attaching the rear ends of the pole piece yoke to the upright portion of the base in the rear. The knurled tension nut consists of a knurled

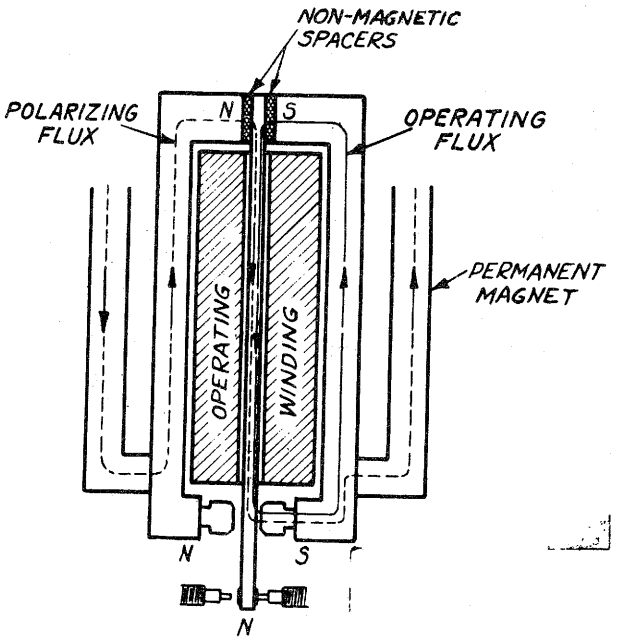

Fig. 22 - Operating Flux and Polarizing Flux Through Armature of 206 Type Relay

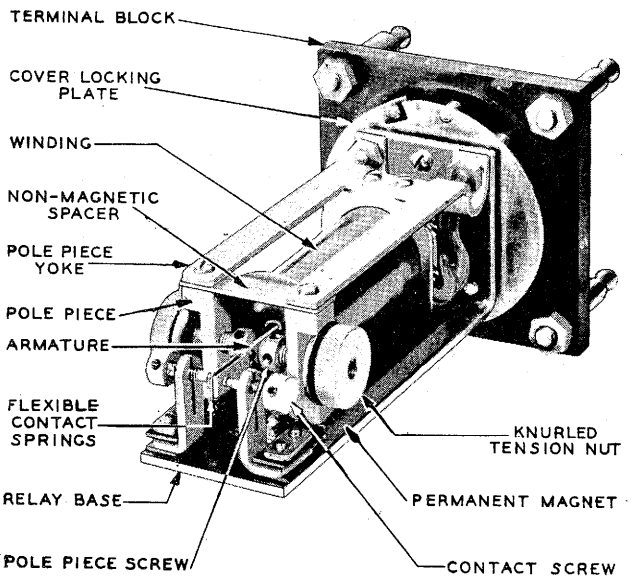

Fig. 23 - 255 Type Relay

screw with a conical shaped spring washer which provides sufficient friction so that the pole piece screws need not be clamped after adjustment. The magnetic circuit of the 255 type is also of the Wheatstone Bridge type and follows in general the arrangement described for the 206 type.

3.40 The 231 and 239 type relays are similar in construction to the 206 type. The pole piece yokes on these relays have, however, been omitted and a Permalloy cover, securely fastened to the frame, is used to form a partial return path for the magnetic circuit. This magnetic arrangement permits the relay to operate on lower ampere turn values while producing the same or greater contact pressures. On the 239 type, which practically supersedes the 231 type, the relay structure proper is mounted upon a supplementary base which is fastened to the frame in such a manner as to prevent shocks and vibrations from distrubing the adjustment of the relay. This relay also has improved features of adjustement and a cover cap design insuring stability of adjustment when the cover cap is removed and replaced. Fig. 24 shows a 239 type relay with the cover removed.

3.41 The 228 type relay shown in Fig. 25 is similar in construction to the 215 type. The contacts of this relay are, however, mounted on a movable contact screw bracket which permits both contacts to be shifted simultaneously by means of a biasing screw to either the left or right side for a biasing adjustment. Instead of being rigidly secured at the rear of the relay, the armature of the 228 type relay is attached to the end of a short reed spring which fits into a clamping device. This particular construction reduces the sensitivity of the relay but causes a higher contact pressure to be obtained, since the polarizing flux need not overcome the opposing force set up by the natural stiffness of a rigidly supported armature.

3.42 The necessary polarizing flux for this relay is furnished by two permanent horseshoe magnets placed around the upper and lower parts of the coil. The two permanent magnets are connected magnetically in parallel, thus furnishing twice as much polarizing flux as the single magnet on the 206 type relay. The magnetic circuit and its action is otherwise the same as that described for 206 and similar type relays. The 228 type relay is equipped with special alloy contacts and is mainly used in open wire and single line telegraph repeater sets.

3.43 The magnetic material used for the pole pieces, pole piece adjusting

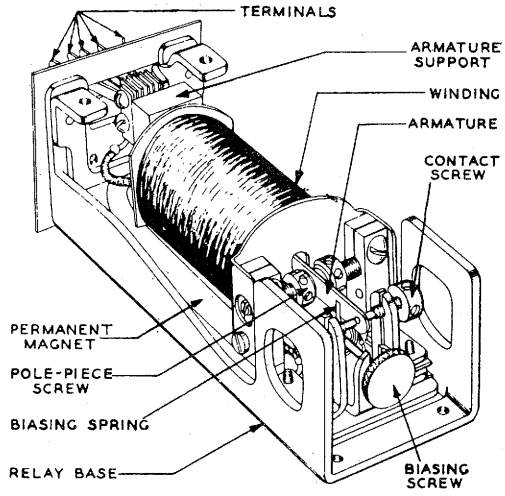

Fig. 24 - 239 Type Relay

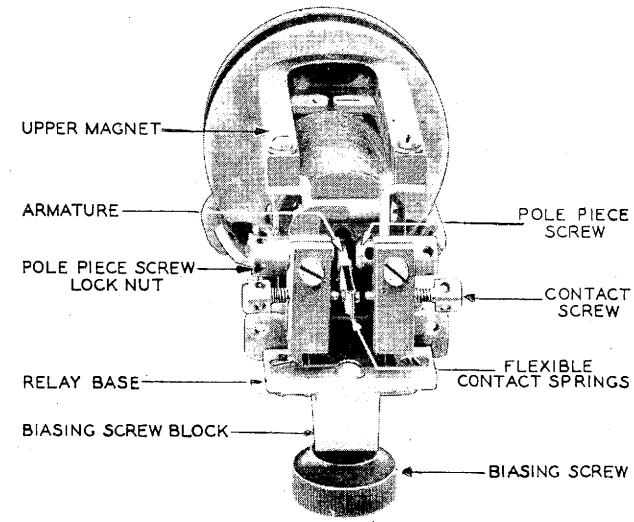

Fig. 25 - 228 Type Relay

screws and armature on the above described relays is either Magnetic Iron or Permalloy. Relays of the 209, 228, 231 and 239 type use Permalloy only, whereas the other types use either Magnetic Iron, Permalloy or both. Code letter designations beginning with FA indicate that the magnetic parts are made of Permalloy.

3.44 The 218-B relay (see Fig. 26 is of an earlier design and does not use the Wheatstone Bridge type of magnetic circuit. A bar shaped permanent magnet, attached to the non-magnetic sub-base of the relay furnishes the polarizing flux. One end of this magnet is in contact with the U shaped frame supporting the two operating windings, while the other end is in contact with the iron supporting block for the

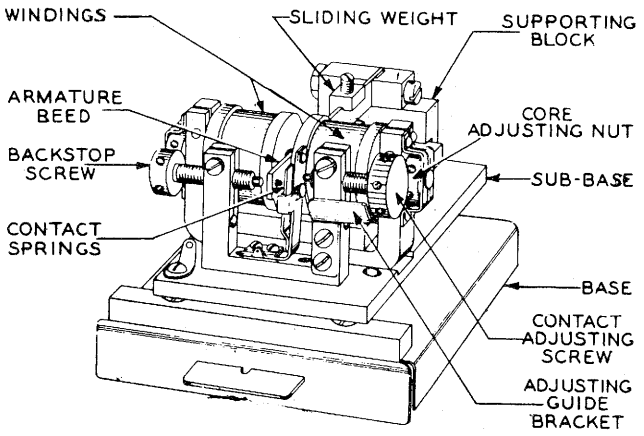

Fig. 26 - 218-B Relay

armature reed. In its normal position, the reed is standing approximately midway between the poles of the two magnet cores. Since the iron supporting block is in magnetic contact with one end of the permanent magnet, the polarity of the free end of the armature reed is opposite to that of the ends of the two cores which are attached to the other end of the permanent magnet. This means that with a current passing through the windings, the operating flux will aid the polarizing flux in one of the adjacent core ends and decrease or reverse the flux in the other so that the armature reed will be attracted toward one core or the other, depending upon the direction of the current. Alternating current of a frequency of 135 cycles is used for operating these relays.

3.45 The contact spring of this relay is short and flexible, and rests against a micrometer adjusting screw with a large graduated head on which each graduation corresponds to a movement of approximately .0005". By means of this screw a normal contact separation of .0015" is obtained. Since this relay is designed to operate on .00025 amp. A-C. at 135 cycles, additional refinements are provided, such as adjustable cores, micrometer movement of the back stop screw, and a small sliding weight on the armature reed for tuning the reed as near as possible to the frequency of the operating current. A relay which is connected in series with the contacts operates when the reed starts vibrating, but does not follow the impulses because a condenser bridged across the winding holds the relay operated by its discharge at the times when the contacts are opened.

3.46 218-B relays are equipped with sponge rubber pads to prevent jarring. Plug type terminals are also used on these relays to facilitate the transfer between operating and test circuits.

3.47 The 266 type relay shown in Figure 27 is primarily intended for use in

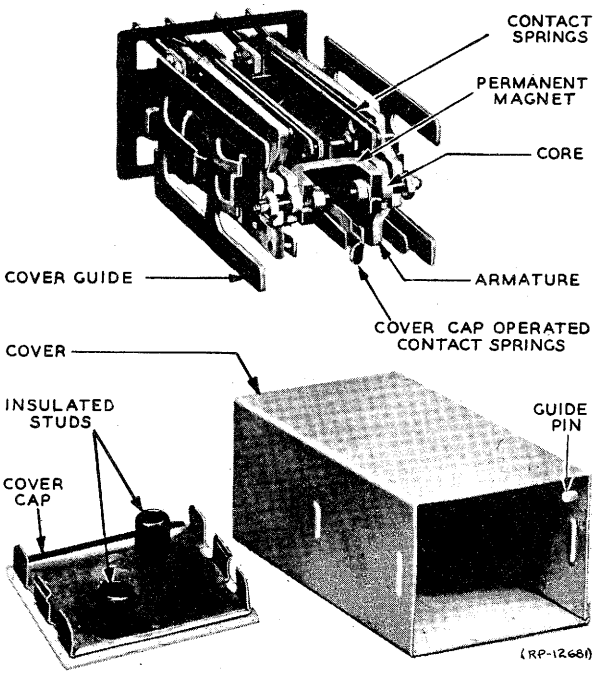

Fig. 27 - 266 Type Relay

panel two party message register circuits. The relay consists essentially of two permalloy R type relay structures held in combination at the rear with a steel bracket and in front with a remalloy permanent magnet. The assembly is enclosed in a removable dustproof metal cover with a removable cap. The cover cap is equipped with two insulated studs for closing a pair of contacts when the cover cap is in place. When the cover cap is removed for inspection or adjustment of the relay, the contacts will open. Two insulated studs instead of one are provided to insure closure of the cover cap operated contact springs regardless of the position of the cover or cover cap. One lip of the cap is partly cut away to clear the guide pin attached to the inside of the cover near the front edge. This pin is to prevent possible substitution of a cover cap without insulated studs which would not close the register circuit.

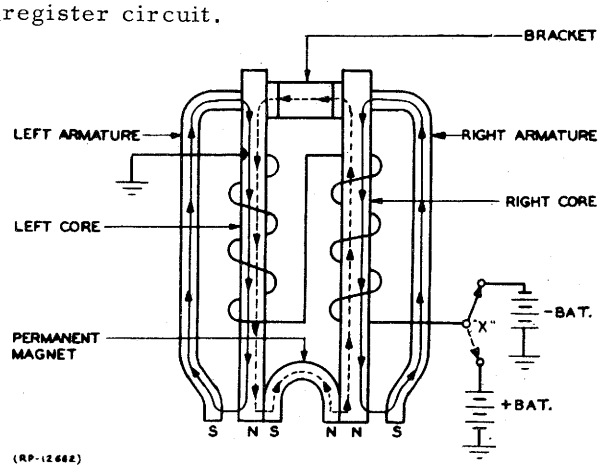

Fig. 28 - Flux Diagram of 266 Type Relay

3.48 The operating principle of the relay is as follows. The magnetic flux produced by the permanent magnet, as indicated by the dotted arrowed lines in Figure 28, passes through a closed magnetic circuit and saturates the two cores. Since the path of the flux is closed, that is without air gaps, the small leakage flux at the armature air gaps is insufficient to operate either armature.

3.49 When negative battery is applied at point "X" in Figure 28, a flux is set up by the windings which will be in the same direction in the two cores, as indicated by the solid lines in Figure 28. This flux will be in the same directions as the flux from the permanent magnet in the left core and in the opposite direction in the right core. Since the cores are already magnetically saturated, no appreciable increase in flux will occur in the left core where the fluxes are in the same direction. The armature on the left will, therefore, not operate. The flux produced by the winding in the core will, however, oppose the flux from the permanent manget, thereby causing sufficient flux to be forced across the armature gap to operate the right armature.

3.50 When positive battery is connected to point "X" in Fig. 28, the flux set up by the windings is in the opposite direction to the flux set up by negative battery. In this case, the flux set up by the windings will cause the left armature to operate and the right armature to remain unoperated.

3.51 The requirements and adjusting procedures for 266 type relays are similar to those specified for flat type relays.

3.52 The 280 type (polarized) relay (Fig. 29) is a recent development designed to supersede the 206 and 239 types. The structure of this relay features an inherently

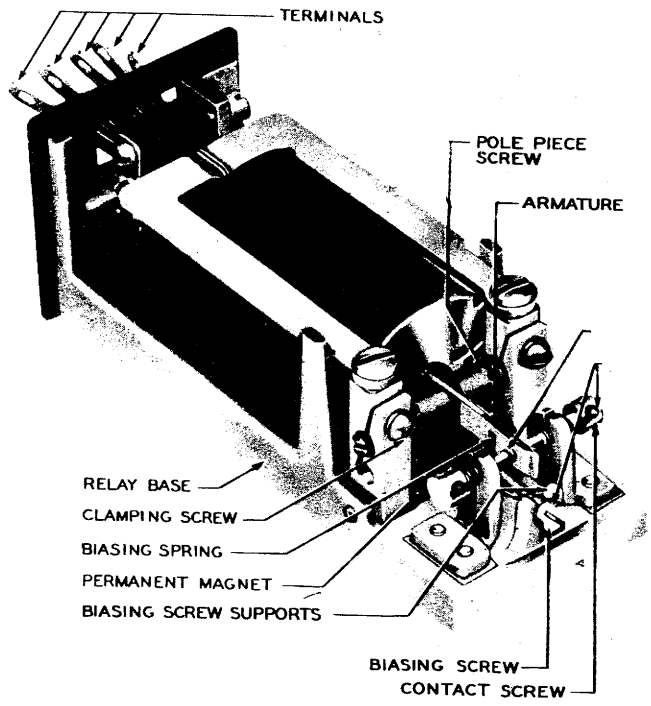

Fig. 29 - 280 Type Relay

stable die-cast aluminum aloy frame. This design of base structure provides material simplification of assembly, more precise alignment of parts with improved stability under vibration, shock, temperature and humidity changes than the former brass frames of the replaced 206 and 239 types. A bar magnet, mounted between the pole piece posts, is used to provide polarization instead of the horseshoe magnet of earlier design relays. The new magnet material is an alloy of iron, molybdenum and cobalt known as remalloy. It provides a magnet which supplies a higher flux density than the older horsehose magnet. The armature is not insulated from the frame. Only the chatterless type armature is provided in this relay.

3.53 The adjustment of polarized relays depends upon the adjustable features of the particular type of relay. In general, changes in armature air gaps or pole gaps (which also change the strength of the polarizing flux), armature travel, contact separation, and biasing spring tension (when provided), are the means used in conjunction with the electrical values for adjusting polarized relays.

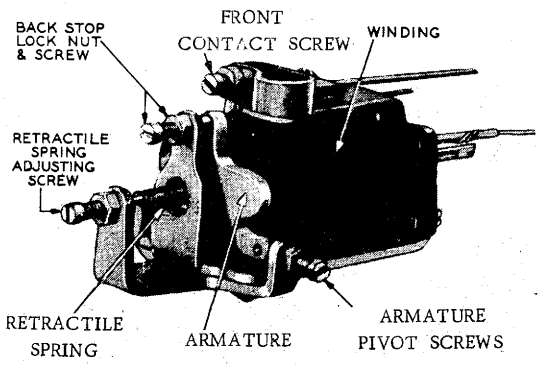

Fig. 30 - 207 Type Relay

(F) Pulsing Relays 207, 208, 213, 268, L N and S Types

3.54 The 207 and 213 type relays, also known as "stepper" relays, are of the telegraph type and differ only in the provision of a dustproof cover on the 213 type. (See Fig. 30). The two electromagnets are connected in series aiding so that, when energized, the end of one magnet core becomes a north pole and that of the other a south pole. A retractile spring, attached to the center of the pivoted armature, is used for restoring the armature to its normal or unoperated position; while adjustable front and back contact, or stop, screws are used to regulate the movement of the armature. In order to insure a fast and reliable operation of these relays in the sender circuits in panel dial offices, an operated armature air gap is used to minimize the effects of residual magnetism. This gap is obtained by adjusting the relay to a specified unooperated armature air gap and a specified contact separation. A connector wire joining the armature and the base of the relay eliminates contact trouble which otherwise might result from dirty armature pivot screws.

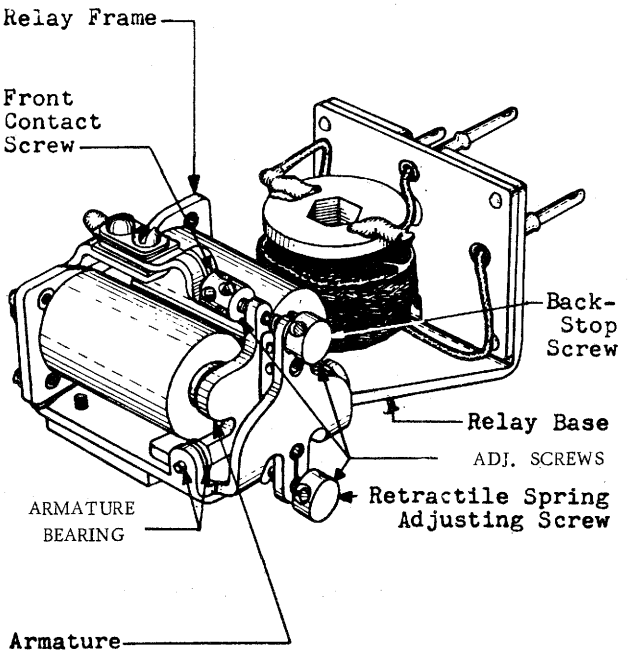

Fig. 31 - 268A Type Relay

3.55 The 268 type relay is a new relay designed to supersede the present 207 and 213 type relays. The 268 type relay has the same general operating characteristics as the 207 type relay. This relay does not offer any gain in capability or working limits over the 207 type, but it does provide better over-all performance because of its greater stability. The relay is brought forward and turned 90° to facilitate gauging and to permit direct sighting through the contact and armature gaps. A reed retractile spring is provided instead of a coil spring in order to give a uniform

buildup of tension, greater stability and to provide ease of adjustment. Two codes have been assigned to this relay. The 268A which has a 200 CL retardation coil (Fig. 31) mounted as an integral part of the relay, and the 268B which has no 200 CL coil. The 268A relay is for use in originating senders where the relay is to be used for revertive pulsing with 208-type counting relays actuated by its contact. Under such conditions, the 200 CL coil is of advantage in minimizing contact sticking trouble tending to prevent the relay from releasing. The 268B relay is for use in No. 1 crossbar full selector terminating senders and similar circuit arrangements where the contact of the relay operates a U-type relay. Under these easier contact conditions, the 200 CL coil is not required in series with the contact.

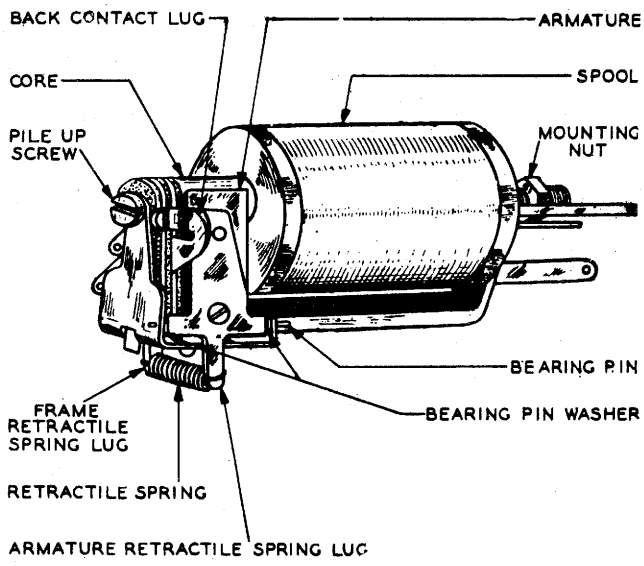

Fig. 32 - 208 Type Relay

3.56 The 208 type relay (see Fig. 32), used as a counting relay in panel dial sender circuits and in other circuits requiring a fast operating and releasing relay, is equipped with a short, light pivoted armature which, on account of its small inertia, permits the relay to more easily follow rapid pulses of current. As on the 207 type relay, a retractile spring holds the armature in its unoperated position; while front and back contact lugs are used to regulate the travel of the armature. Fast operation and quick release are insured by the use of a light weight armature, a short armature travel and the establishment of an operated armature air gap.

3.57 The L, N and S type relays are pulsing relays of the flat punched type. These three types are practically identical in design, except that the N and S types are provided with a removable crosstalk-proof

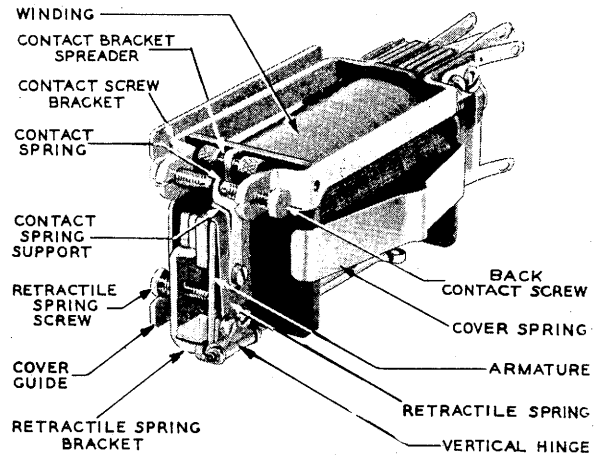

Fig. 33 - "S" Type Relay

cover and cap and that a laminated core is used on the N type. The magnetic circuit of these relays is similar to that of the 208 type, a return pole piece and a short armature being used. The armature is equipped with either a chatterless contact spring (a light flexible spring), which normally rests against a contact spring support, or a solid contact spring. A flexible contact spring insures contact follow and consequently a better and longer contact closure, whereas a solid contact spring is used when speed of operation is the predominating factor. A flat phosphor bronze spring is used as a retractile spring. The tension of this spring is regulated by means of a finely threaded screw in the retractile spring bracket, permitting a much finer tension adjustment than can be obtained with the helical retractile springs used on the 207 and 208 types of relays. The base gap acts in the same manner as the operated armature air gap on stepping or counting relays, but is not dependent upon armature travel and contact separation. Contact screw brackets equipped with contact screws are used for the front and back contacts. The brackets bear against contact bracket spreaders instead of

the spoolhead to avoid changes in adjustment caused by a slight contraction of expansion of the spoolhead with changes in atmosphere. Fig. 33 shows an S type relay with the cover removed.

(G) 221, 222, 223, 224, 225, 247, 248, 251, and 252 Type Relays(Step-by-Step Relays)

3.58 These relays are known as step-by-step relays because they are largely associated with step-by-step equipment. The coil of these relays is wound on a round core which is fastened to the heelpiece by means of a fillister head screw. The armature is short and is attached to the forward end of the heelpiece by the armature yoke. A phosphor bronze pin secured to the armature and turning in holes in the armature yoke, forms a bearing which will not bind, will wear very slowly and is practically without side play. The armature yoke is attached to the heelpiece by means of a single armature yoke set screw, permitting an easy adjustment of the heelpiece air gap. A small brass screw passing through the armature at a point directly opposite the center of the core is used to regulate the operated armature air gap to prevent the armature from sticking to the core due to residual magnetism. This screw is known as the "Residual Screw". See Fig. 34.

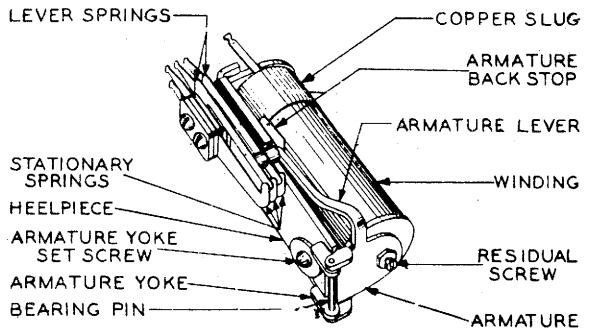

Fig. 34 - 221 Type Relay

3.59 For operating the contact springs, the armature is equipped with either one or two armature levers, or arms, ending in a hard rubber armature stud. The contact springs are mounted at the back end of the heelpice, with the contacts in front, except on 225 type relays where the contact springs are mounted in front and the contacts are facing the rear. To facilitate the adjustment, the relays are arranged for either left or right hand mounting, with the contact springs in a vertical position on the side of the relay. The exception to this method of mounting is the 225 type relay, which mounts directly on the casting of 197 or 198 type switches, with the contact springs on top in a horizontal position. Relays arranged for mounting on the left-hand side of the mounting plate include the 221, 223, 247 and 251 types, while the others, that is, the 222, 224, 248, and 252 types, mount on the right-hand side. Other outstanding differences in construction between the various types are given in the following paragraphs.

3.60 As previously mentioned, either one or two armature levers or arms are used for operating the contact springs. The

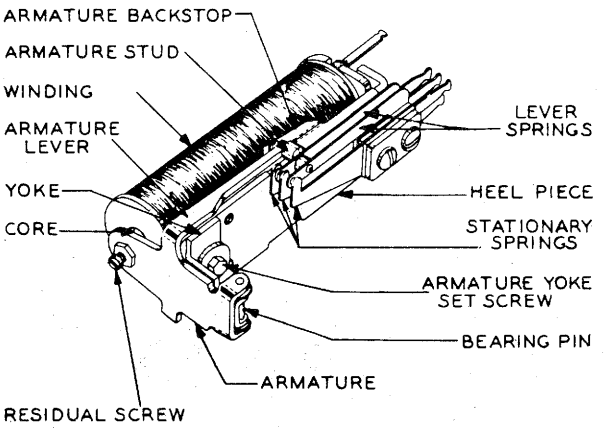

Fig. 35 - 248 Type Relay

two lever arrangement is used only on the 223 and 224 types and allows as many as 34 springs to be placed on one relay. The position of the bearing pin with respect to the rest of the armature determines the ratio of the travel of the springs (measured at the contacts) to the travel of the armature (measured at the residual screw). This ratio is approximately 2-3/4: 1 on the relays, except on the 247 and 248 types which have a ratio of approximately 1 : 1. See Fig. 35. The 247 and 248 types are slow releasing relays with a copper sleeve or slug over the core and use the 1 : 1 ratio lever arm to obtain greater release time capabilities than is possible with a 2-3/4 : 1 ratio arm. A copper slug or head over part of the core at either the front or rear, or a copper sleeve over the full length of the core is also used on 221, 222, 223 and 224 type relays to obtain a slow releasing or slow operating effect. A detailed

explanation of these features is given under the heading of "Slow Acting Relay".

3.61 The 225 type relay is provided with a short coil, its length being about 1/2 of that used on the other relays. Since the armature lever ratio is 2-3/4 : 1, the contact springs are mounted on the front end of the heelpiece and the contacts are facing the rear.

3.62 The 251 and 252 type relays are 3 pole electro-polarized relays. See Fig. 36. These relays are equipped with two separate windings, a front winding for operating the relay and a rear winding for furnishing the polarizing flux. Between these windings is located a specially shaped iron washer which is attached to the relay core. An iron detail attaches to this washer and extends along the outside of the front coil to the front of the relay to serve as the front pole piece and armature back stop. The front pole piece is equipped with an adjustable back stop screw to permit variation of the armature travel. The operation of this relay is briefly as follows:

3.63 In its normal unoperated position, the armature is resting against the back stop screw on the front pole piece. When the polar winding alone is energized it is held in this position by the polarizing flux instead of being attracted to the core, because the polarizing flux is splitting two ways - (1) through the core, armature air gap, armature and heelpiece and (2) through the center pole piece, arms of front pole piece, armature and heelpiece. Since the reluctance of the second path is considerably less than that of the first path, due to the lesser air gap, the major portion of the polarizing flux will flow through the second path and therefore hold the armature in that position.

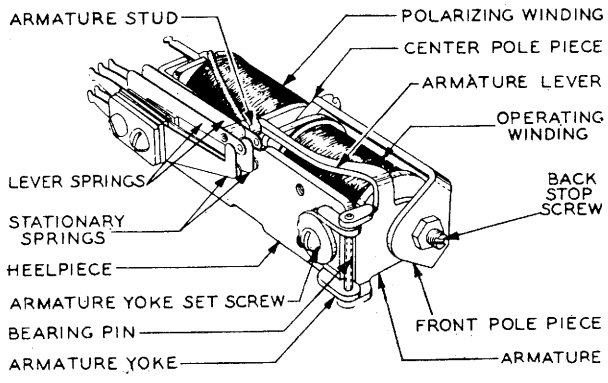

Fig. 36 - 251 Type Relay

3.64 When the operating winding is energized in the same direction as the polarizing flux, the armature will be attracted to the core, aided by the polarizing flux through the core, provided the operating flux is sufficient to overcome the effect of the polarizing flux through the front pole piece and the tension of the operating springs. At the instant the armature starts moving, that is breaking magnetic contact with the back stop screw, the relative strength of the polarizing flux through the two paths is changing, finally becoming the reverse from that with the armature in the unoperated position.

3.65 When the operating current is applied in the reverse direction, the armature will not move from its unoperated position, unless the applied operating current is increased sufficiently to overcome entirely the effect of the polarizing flux through both paths.

3.66 The three pole electro-polar relay is superior to the ordinary electro-polar relay in the following characteristics: The polar winding may be designed to have a large number of ampere-turns without danger of causing operation when this winding is energized alone. This large number of ampere-turns in the polar winding aids in operating large spring loads and in providing very quick operation after reversal of the line winding because the polar flux is made useful in assuring operation by the energization of the operating winding with aiding polarity. Increase in ampere-turns of the polar winding up to the maximum permissible values does not demand a like increase in ampere-turns of the line winding to prevent operation with the windings opposing. A comparatively large number of ampere-turns may be developed by the line winding where it opposes the polar winding without causing false operation of the relay.

3.67 In general, step-by-step relays are adjusted to meet certain heelpiece air gap, residual and back stop requirements, followed by an adjustment of the contact springs to meet contact follow, contact separation, sequence and electrical requirements.

(H) Trip Relays 114 and 198 Types

3.68 These relays are tubular in shape because a round iron shell is used as the return pole piece. The armature is mounted between pivot screws and is held in the unoperated position by means of either a flat or coiled retractile spring. The two types of relays are similar in shape, except that the 198 type is longer and has two windings. See Fig. 37.

3.69 Most of these relays are used as trip relays in incoming trunk circuits to trip or cut off the ringing current

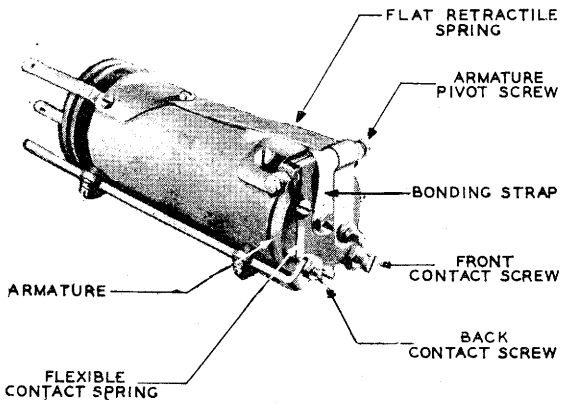

Fig. 37 - 114 Type Relay

when the called subscriber lifts the receiver off the telephone. Relays used as trip relays have a copper sleeve over the core and use a flexible contact spring. A bonding strap insures a good electrical connection between the armature and core which form a part of the local circuit to be closed by the contacts of the relay. The effect of the copper sleeve is to lower the impedance of the operating winding. This is due to the fact that when alternating current (ringing current) passes through the winding, the copper sleeve acts as a short-circuited secondary winding of a transformer, setting up an opposing flux which decreases the main flux and, therefore, the inductive reactance in the winding. The tubular iron shell used as the return pole piece provides an excellent magnetic return path and, in addition, prevents magnetic interference with adjacent apparatus.

3.70 On some recent codes of 114 trip relays, developed in connection with 1500 ohm subscriber loops, such as the 114KA relay, a copper head is used in addition to the copper sleeve to further reduce the impedance of the relay. An enlarged pole face is also used on these codes to reduce the magnetic reluctance so that the relay will operate on less current. Fig. 38 shows a cross-section of this relay.

3.71 A relay operating on alternating current and under close marginal conditions (which is the case with the trip relay) will necessarily have a tendency to operate only at the peak of the wave, especially if the operating point is dependent upon the tension of the retractile spring. In order to insure longer operation and also to stabilize the operation so that the relay will not respond to the non-operate current, it is desirable to use some means to make the relay depend more upon effective current values than upon instantaneous values. The flexible contact spring used on these relays allows a reduction in retractile spring tension by preventing contact separation until the armature has moved a considerable portion of its travel, and the low retractile spring tension in turn allows the inertia of the heavy armature to maintain a stabilizing effect upon the point and time of operation of the relay.

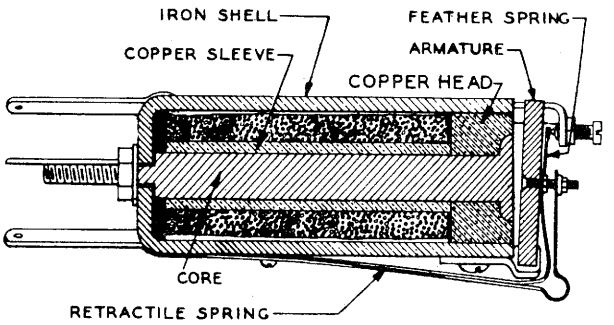

Fig. 38 - Cross-Section of Trip Relay

3.72 Trip relays are adjusted by setting the contact screws so that certain operated and unoperated armature air gaps and contact separations are obtained, and then changing the tension of the retractile spring to meet the operate and non-operate electrical requirements.

(I) Multi-Contact Relays 229, 230, 232, 245, 254, 263 and 264 Types

3.73 Multi-contact relays, as the name implies, are relays capable of operating a large number of contact springs. the 229, 230 and 232 types are essentially gang relays, similar to a number of individual relays on a mounting plate, but operated by a common electromagnet. Briefly, they consist of a mounting plate with a large number of spring assemblies operated by means of a draw bar attached to an electromagnet. The armature moves on a bearing pin attached to the magnet frame and is equipped with an armature arm, which is at right angles to the armature and operates the draw bar. The leverage of the armature arm is such that when operating, the draw bar moves about twice as far as the armature. The magnet is of the efficient, short, thick spool type and is partially enclosed with a soft iron frame, which acts as the return path for the flux. See Figs. 39 and 40.

3.74 The 229 type relay is a single unit relay, while the 230 and 232 types are double unit relays having two magnets, each of which operates its own draw bar and contacts. The 230 and 232 type relays differ mainly in number and type of spring combinations and the addition of a condenser and resistance between the two units of the 232 type. The resistance and condenser provide protection for the contacts of the relays which operate the magnets. The 229 and 230 types are intended for use on panel dial decoder frames while the 232 type is used in the master relay circuit for regulating repeaters. The present relays handle from 16 to 52 contacts.

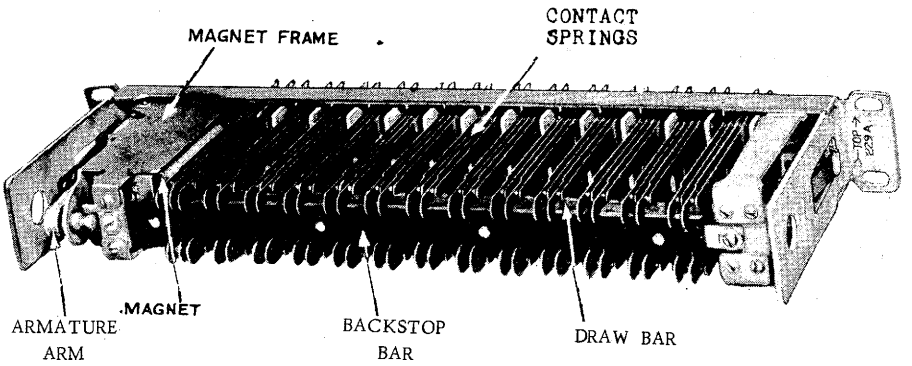

Fig. 39 - 229 Type Relay

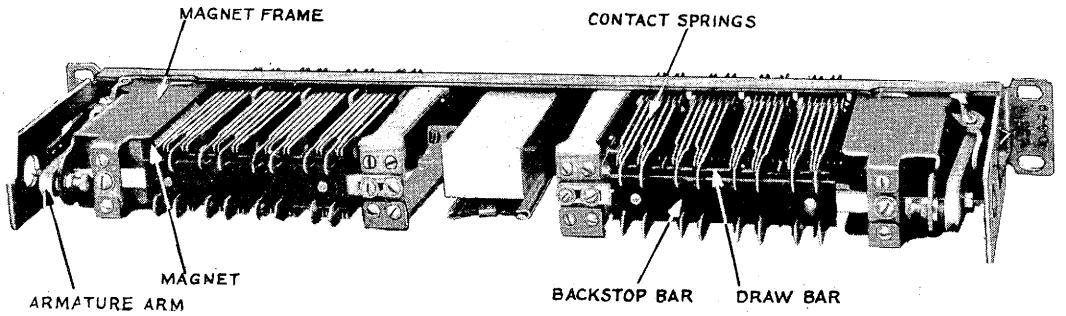

Fig. 40 - 232 Type Relay

3.75 The 245 and 254 type relays are multi-contact relays primarily intended for use in the crossbar dial system. Each of these relays consists essentially of a frame equipped with ten groups of contact springs, two magnets and two armatures. Half of the contact groups can be operated by energizing one of the magnets, or the entire ten groups can be operated by energizing both magnets. Each armature controls from 15 to 30 pairs of contacts and by operating the two halves in parallel, a maximum of 60 simultaneous connections can be made. See Fig. 41.

3.76 The contact springs on these relays are mounted between long strips of insulating material, forming one single large pile-up instead of individual pile-ups as on the other relays. At the front, the stationary contact springs are securely held in place in another pile-up of insulating strips. Twin contacts are used and the operating springs are bifurcated to insure contact reliability. The advantages to be gained from this contact arrangement are the same as those given for U and Y type relays. The operating springs are actuated by pressure of the armature against small insulating studs which are fastened in the springs and pass through holes in the stationary springs. The armatures are of the knife edge type, held in place by locating and retaining springs. Since the armature is in direct contact with the heelpiece, a low reluctance magnetic circuit is assured. To prevent sticking, the armature is faced with a thin piece of nickel silver attached by spot welding.

3.77 245 and 254 type relays mount vertically, with the spring pile-up of one relay nesting between the magnets of the adjacent relay. The two types differ only in the arrangement of the contact terminals. On the 245 type, the terminals of all stationary contact springs and the terminal of one operating spring in each group are arranged for individual wiring. The terminals of all other operating springs are arranged for horizontal strapping. On 254 type relays, the terminals of all the contact springs are arranged for individual wiring, none of these terminals having the special arrangement for horizontal strapping.

3.78 263 and 264 type relays are essentially the same as the 245 and 254 types. However, provision is made for adjusting individual spring pile-ups, by means of adjustable tabs on the armatures.

3.79 The adjustable features of multi-contact relays are similar to those of flat type relays.

(J) Barrel or Round Type Relays - 122, 125, 149, 162 and 178 Types

3.80 These relays are of an earlier design and are generally known as "Barrel" or "Round" type relays because of their round or barrel shaped covers. The above types are almost identical in construction except for changes in contact arrangement, and in the provision or

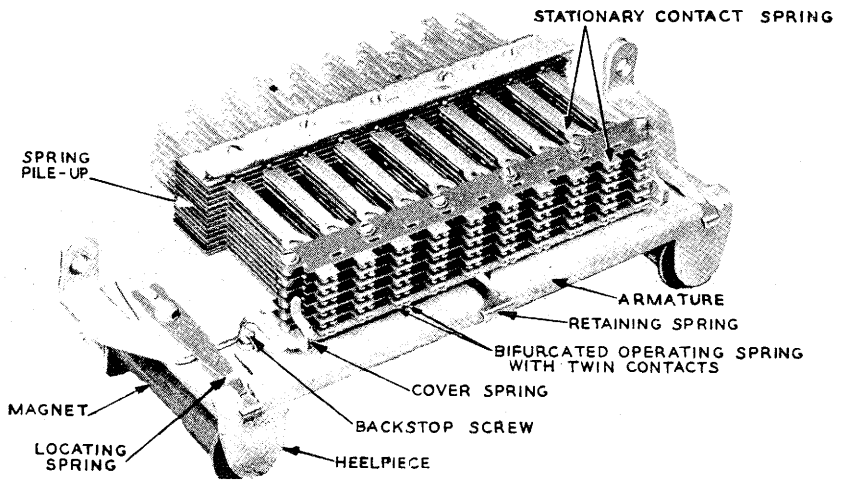

Fig. 41 - 245 Type Relay

non-provision of a copper head or sleeve over the core for a slow operating or slow releasing effect. The purpose of a copper head or sleeve is explained in the section covering slow acting relays. See Fig. 42.

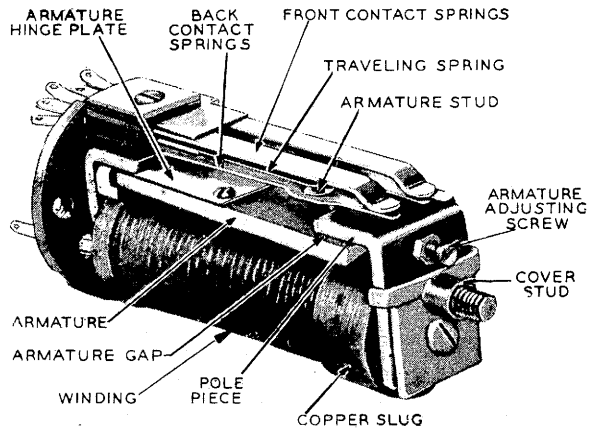

Fig. 42 - 178 Type Relay

3.81 Barrel type relays are still used to some extent as general switching relays on additions to existing installations and where a slow acting or slow releasing effect is necessary. The armature is at the side and is hinged to the rear bent over pole piece by means of a steel hinge plate. The front bent over pole piece is equipped with an adjusting screw for adjusting the armature travel. From one to three sets of spring combinations, clamped to the rear pole piece and resting on the front pole piece, are operated by hard rubber studs attached to the armature. Stop pins, or non-freezing discs, welded to the armature are used on a number of relays of this type which do not have a slow release requirement. The purpose of these stop pins is to establish an operated armature air gap which prevents the relay armature from sticking to the core due to residual magnetism, thereby insuring a quick release.

3.82 Individual dustproof covers of either brass or iron are used on practically all of these relays. An iron cover (cross-talk proof) is used whenever it becomes necessary to shield the relay against stray flux from adjacent relays. The principle of shielding against stray flux is explained in the section covering B and G type relays. Changes in armature travel, stud gap, contact follow, and tension of the contact springs are the means used for adjusting these relays to meet their electrical requirements.

(K) 253 Type Relays

3.83 The 253 type relay shown in Fig. 43 is used with small batteries for P.B.X. and community dial office power plants to control the charging rate and to switch counter EMF cells in and out of the circuit in order to maintain the battery voltage at the desired limits. In appearance it is similar to the 208 type used as a counting relay in panel dial sender circuits. The operating characteristics, however, are quite different. The 253 type is compensated for changes in resistance of the winding and changes in voltage of the batteries due to variations in room temperature.

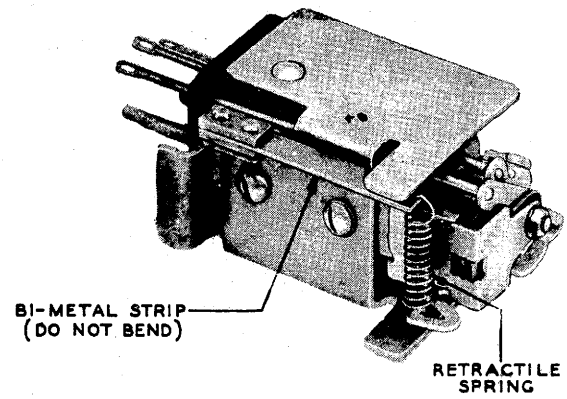

Fig. 43 - 253 Type Relay

3.84 The temperature compensation is obtained by a bi-metallic strip attached to the underside of the relay, as shown in the bottom of Fig. 43, which changes the tension of the retractile spring. As the temperature rises, the bi-metallic strip flexes to lessen the spring tension, thus causing the relay to operate on a lower voltage. As the temperature drops, the reverse action takes place.

3.85 Since the voltage of a battery decreases as the temperature rises, the fully charged voltage will vary with changes in room temperature. This variation in battery condition is compensated for

by using a 253 type relay in a suitable circuit and mounting it in close proximity to the battery so that it is subjected to the same temperature condition.

3.86 The adjustment of 253 type relays is on a voltage basis and requires that consideration be given to temperature conditions. For this reason it is important that the relay be kept energized as continuously as possible and that the cover be removed only for adjustment purposes. Adjustment for electrical requirements is made by changing the tension of the retractile spring and adjusting the resistance in series with the relay.

(L) Voltmeter Relays - 260 Type Relays

3.87 The type of relay illustrated in Figs, 44 and 45 is known as the 260 type. In its essential form it is a voltmeter of the permanent magnet-moving coil type equipped with a contact arm which moves between two stationary contacts. The contacting arrangement is visible through a glass window in the cover.

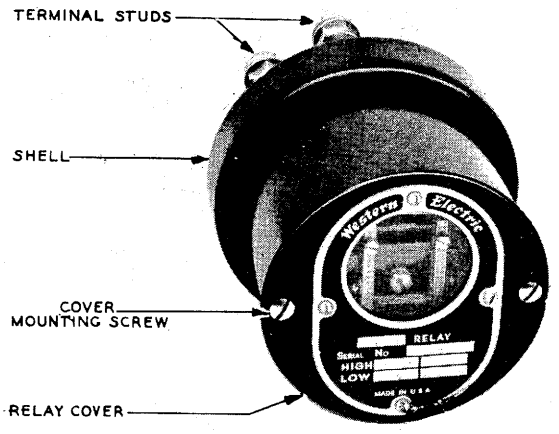

Fig. 44 - 260 Type Relay

3.88 While the principle of operation is the same as that of the conventional permanent magnet-moving coil type of meter, the layout of the parts does not follow the usual arrangement. Instead of a large horseshoe magnet with soft iron pole pieces surrounding the moving coil, the permanent magnet of the 260 type relay consists of two rectangular bars of "Remalloy" (an alloy with high coercive force) placed inside the moving coil. Surrounding the coil and in close proximity to it is the heavy round steel shell which forms the return path for the flux and also serves as a magnetic shield. The moving coil is otherwise of the conventional type with jeweled bearings and torsion springs. Connection to the winding and contacts is by means of terminal studs which project through the base of the relay. Two of these studs are also used for mounting purposes. 260 type relays are made for single and double voltage ranges and for differential purposes.

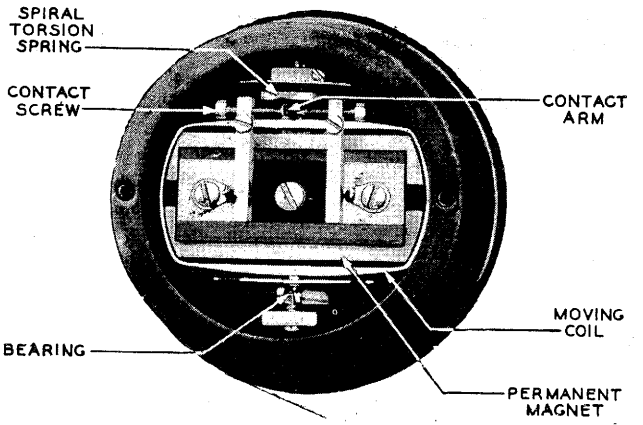

Fig. 45 - 260 Type Relay - Cover Removed

(M) Sensitrol Relays (Weston Model 705)

3.89 The sensitrol relay (see Figure 46) is essentially a direct current meter of the permanent magnet-moving coil type equipped with one or two stationery contacts. The stationary contact is a small powerful permanent magnet attached to the end of a supporting arm. The mating contact consists of a silver plated iron "rider" mounted on the pointer or contact arm. When the operating torque set up by the current passing through the moving coil moves the iron "rider" of the pointer into the magnetic field of the stationary contact, the iron rider is drawn firmly against the stationary contact, thus closing the contacts. This arrangement insures good contact and prevents chattering. The contacts remain closed until they are reset either manually, or electrically by means of a solenoid mounted on the back of the relay.

3.90 Figure 46 shows a sensitrol relay with two stationary contacts and arranged for manual reset. On this relay, each stationary contact and associated index are fastened to a common arm which is moved to the desired operating point by means of a knob on the front of the case. This knob is also used to disengage the pointer and reset the relay. On sensitrol relays equipped with a solenoid, the stationary contacts are usually fixed and the adjustable index when turned changes the position of the control spring similar to the action of a zero corrector. Adjustment of sensitrol relays in the field is usually restricted to changes in the zero adjuster screw setting.

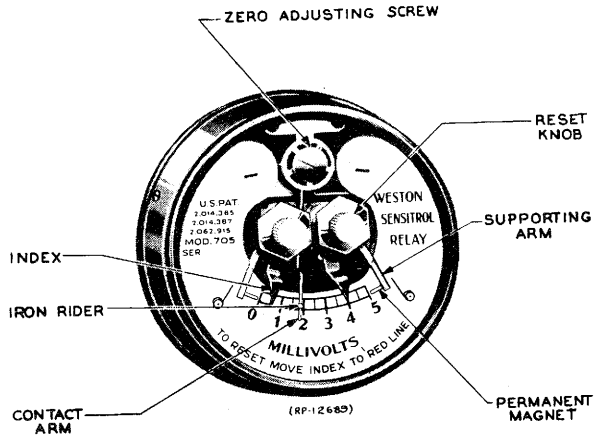

Fig. 46 - Sensitrol Relay

(N) Adlake Relays - KS-7800 Series.

3.91 Where time delays of relatively large duration are required, slow acting relays of the KS-7800 series ("Adlake" relays) are used. An external view of an "Adlake" relay is shown in Figure 47.

3.92 The operating mechanism, (see Figure 48), is completely sealed in a glass tube. This tube which is surrounded by the winding contains a hollow cylindrical iron plunger floating on mercury. The tube also contains two electrodes, one of which is always in contact with the mercury and the other insulated from the mercury. A small cup of insulating material which contains mercury is mounted at the top of the insulated electrode thus providing the mercury contact.

3.93 The relay with the normally open contacts functions in the following manner. The plunger, when the winding is energized, is pulled down into the mercury thereby causing an immediate displacement of the latter. The rising mercury column traps the inert gas which is in the glass thimble surrounding the electrodes. A further rise of the mercury to a level sufficient to make contact with the mercury in the insulated cup depends upon the time required for the gas to flow through minute pores of a piece of ceramic fused in the top of the thimble. When the winding is de-energized the iron plunger immediately restores to normal thereby causing the mercury to assume its normal level. The recession of the mercury opens the contacts and permits the gas pressure inside and outside of the thimble to become again equalized.

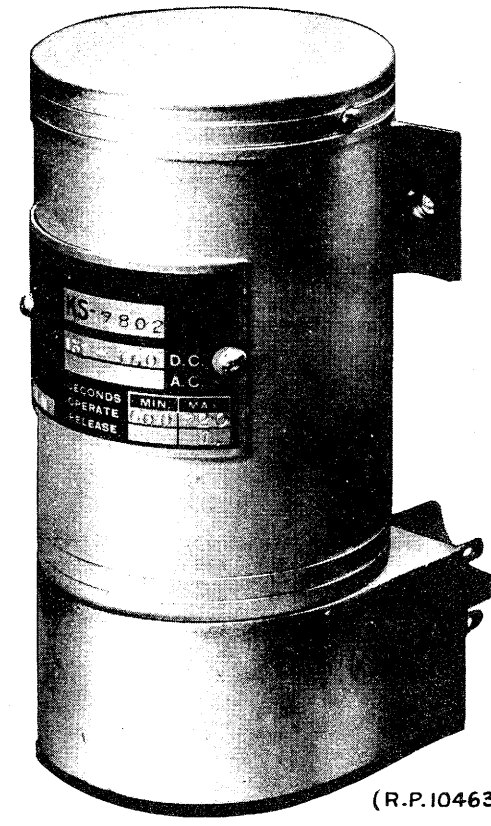

Fig. 47 - KS-7802 Relay (Adlake)

3.94 The relay with the normally closed contact functions similarly to the relay with the normally open contact as described above, except that the iron plunger is pulled upwards instead of downwards when the winding is energized. This causes the mercury level outside of the thimble to drop. The mercury inside of the thimble then recedes under control of the gas passing through the ceramic plug and eventually opens the contact. When the winding is de-energized the plunger returns to normal which in turn causes the mercury to assume its original level.

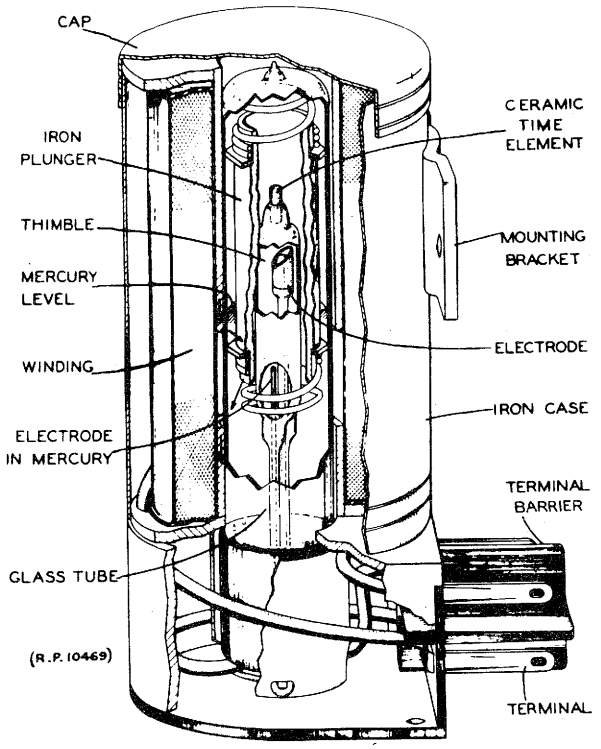

Fig. 48 - Sectional View of KS-7802 Relay

3.95 Relays of the KS-7800 series are not adjustable, as the required time delay is determined at the time of manufacture by the selection of the proper ceramic time element. They are made to delay the opening, or closing, or both of a single normally open or normally closed contact from 3/10 second to 12 minutes or more. While the majority of the relays are equipped with windings suitable for operation on direct current, some of the relays operate on alternating current or on both.

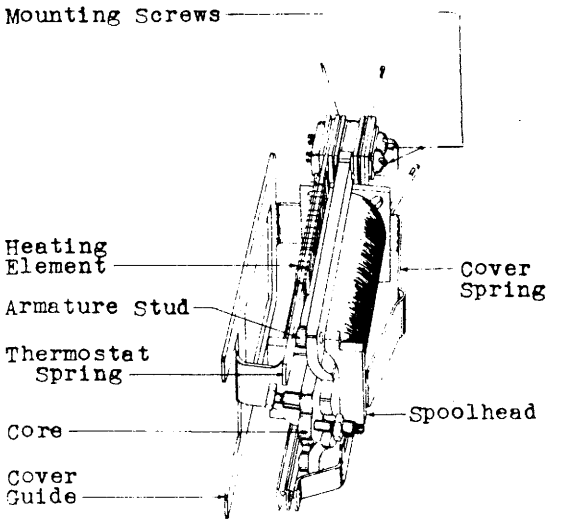

Fig. 49 - 236 - Type Relay

(O) Thermal Relays - 236 and 271 Types

3.96 The 236 and the 271 type relays (See Fig. 49) operates on the thermal principle. They have the same structure as the E type relay, except that the core of the F type is used in order to obtain the adjustable stop pin feature. In addition to the standard E and F type parts they are equipped with a thermostat metal spring mounted in place of one of the regular spring combinations. The thermostat metal spring consists of a strip of brass and a strip of steel permanently welded together throughout their entire length. It is wound with a few turns of high resistance wire. When current is applied to the coil winding, the relay operates and closes a contact which applies current to the thermostat spring winding. The spring is heated and begins to bend toward the armature due to the unequal expansion of the brass and steel strips of which it is composed. When the force applied by the thermostat spring to the armature is sufficient to overcome the magnetizing force due to the current in the relay coil winding, the armature is forced to its unoperated position, which

opens the circuit of the heater winding of the thermostat spring. The thermostat spring cools and gradually returns to its normal position, relieving the pressure on the armature. The armature again operates and the cycle is repeated as long as current is kept continuously on the relay coil winding and the current to the heater winding of the thermostat spring is alternately closed and opened. With 24 volt current the following time intervals have been obtained with the 236 type relay: Heating time - 16 seconds ± 2 seconds . Heating plus cooling time - Total period - 60 seconds ± 15 seconds. Although the 236 relay will give long delayed time intervals it is not satisfactory for use where time intervals are critical due to the possible wide variations of heating and cooling times.

(P) Mercury Contact Relays

3.97 275 and 276 Type Relays.

(a) Mercury contact relays (See Figs. 50 and 51) are designed to provide long life with a high degree of reliability, freedom from open contacts due to dirt, fast operating and releasing times and to permit the switching of high current loads when provided with adequate contact protection. They are now being manufactured for the new No. 5 Cross-bar System for the Automatic Message Accounting center and for certain applications in P.B.X. power plants.

(b) The 275 and 276 type relays each contain one 218-A sealed-in glass mercury contact switch inserted in an operating coil that has the same dimensions as the coil of the U type relay. The switch and coil assembly are wired to a small wafer octal base and housed in a gray metal vacuum tube type of covering which serves as a loosely connected return path for the switch. The tube is filled with a potting compound to fix the position of the various parts. The drawings attached show cross-sectional views of the 275 and 276 type relays.

(c) The 218-A switch, the construction of which is illustrated in the drawing of the 275 type relay, is a 5 terminal switch of the transfer type with a single armature, two separate make contacts (normally open) and two separate break contacts (normally closed). All contacts surfaces are covered with a thin film of mercury maintained by capillary action from a pool of mercury at the bottom of the switch. Each of the two make contacts is welded to a 52 alloy rod, which is magnetic and is sealed in the top of the switch. Each of the two break contacts is welded to a rod, which is monel metal and nonmagnetic at the lower end and 52 alloy at the upper end where it is sealed in the top of the switch. These contacts are bar type platinum contacts with their base formed to fit the round rods to which they are welded.

(d) The armature contact is made from a piece of round platinum wire that is formed into a T shape. The lower part of the T is welded to the armature. The upper part of the T extends above the armature with the two horizontal arms engaging the two break contacts on one side when unoperated and the two make contacts when operated. The space between the adjacent wires of the T forms a capillary path for the mercury. The armature, which is a rectangular permalloy plate, has two 52 alloy wires welded on it that butt against the two lower ends of the T-shaped armature contact and extend the capillary path downward. The main operating gap is between the top of the armature and the two make contact rods, the travel of the armature at this gap being limited by the fixed contacts.

(e) The armature is attached by means of a flat steel hinge spring to a 52 alloy tubular stem that is sealed in the bottom of the switch. A lower pole-piece is mounted beside the armature opposite the hinge spring and provides a relatively large area hinge gap as a magnetic connection to the tubular stem.

(f) The spaces between the armature, hinge spring and lower pole-piece are filled with mercury by capillary action and this provides some fluid damping of the armature motion. The mercury pool in the bottom of the switch extends up to about the bottom of the hinge gap. About .3 cu. cm. of mercury, followed by hydrogen at a pressure of 250 pounds per square inch, are introduced through the tubular stem and finally the stem is sealed at the bottom by welding.

(g) The armature and make contact rods are of magnetic material and with the switch inserted in an operating coil the armature is pulled toward the make contacts when the operating coil is energized. Upon opening the operating coil circuit the back tension of the armature spring restores the armature to close the break contacts. The operating characteristics of the 218A switch are fixed by its design and the manufacturing control requirements are the same for all switches. No readjustments of the switch characteristics can be made after manufacture and no maintenance can, therefore, be applied to restore a defective switch.

(h) A permanent magnet is furnished only on 276 type relay, and is the feature that distinguishes this relay from the 275 type. The magnet provides means for factory adjustment of the relay characteristics by biasing the armature. This increases the operate sensitivity in the direction to reduce the operate current through the winding, and makes the 276 type more sensitive and more marginal than the 275 type. In one coded form, the 276D, the relay is biased to a point of being a fully polar relay, that is, to the point where a current through the winding, approximately equal and opposite to the operate current, is required to release the relay.

(i) These relays should preferably be mounted in a vertical position but may be mounted as much as 30 degrees from the vertical without affecting their characteristics. Wherever possible these relays should be mounted where they will be free from magnetic interference.

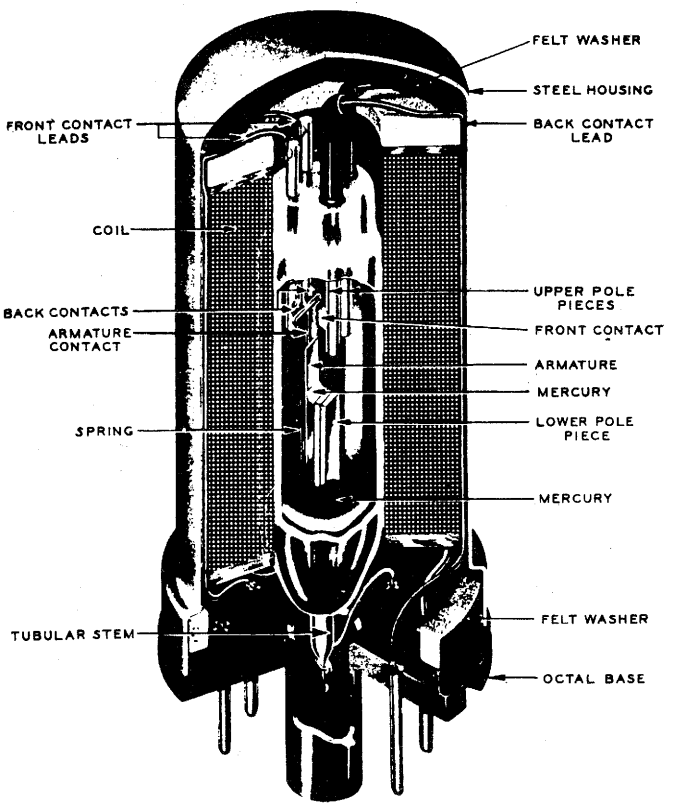

Fig. 50 - Mercury Contact Relay - 275 Type

(j) Caution must be exercised in removing these relays from their sockets to prevent breakage of the centering pin and consequent loss of the positioning indicator. A 603A tool is available for removing mercury contact relays from their sockets. No attempt should be made to disassemble a 275 or 276 type relay, since the glass contact switch element mounted within the outside steel shell contains a gas under high pressure, (250 pounds per square inch). In case the glass envelope of an exposed switch element is broken, pieces of glass may be propelled with sufficient force to cause personal injury, particularly to the eyes.

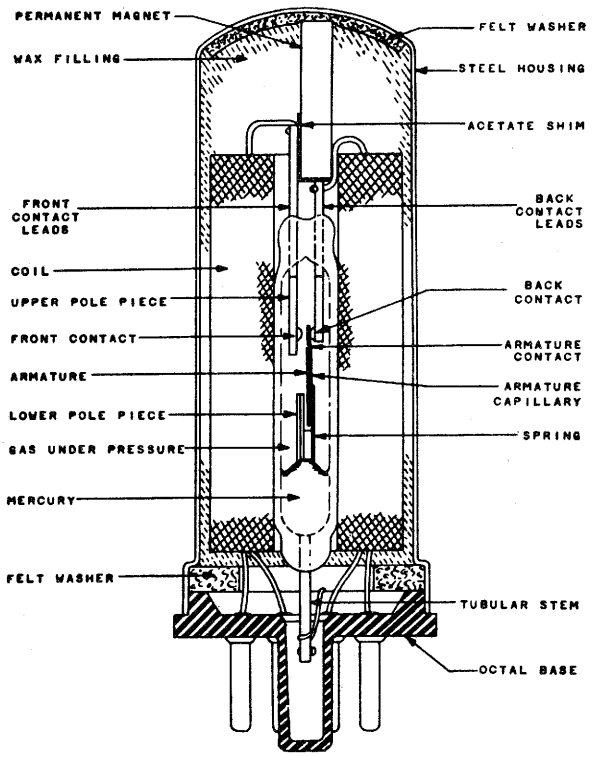

Fig. 51 - Cross Section of 276 Type Relay

4. ALTERNATING CURRENT RELAYS

(A) General

4.01 Although a number of relays previously described, for example, the trip relays, and polarized relays of the 209 and 218 types, are operated on alternating current, they are not considered alternating current relays because the armature vibrates (chatters) or follows the impulses of the alternating current through the operating winding. The reason for this vibrating is covered in 4.02.

4.02 When alternating current passes through the winding of a relay, a flux is set up in the magnetic circuit, the direction of which is constantly changing in accordance with the reversals of the alternating current. The direction of the flux, however, does not affect the attraction between the armature and core, since during either the positive or negative half cycle of the alternating current wave, unlike poles (which attract each other) are set up in the core and armature ends. At the time the alternating current wave passes through zero, however, no flux is generated, and consequently, no attraction between armature and core takes place. This means that the armature tends to fall away during that part of the cycle in which the attraction is less than the restoring force. Consequently, the contacts associated with the armature do not remain operated but alternately open and close. This condition has been partly overcome on the 186 type relays and almost entirely eliminated on the J type relays. These relays are known as alternating current relays and are described in 4.03 to 4.10 inclusive.

(B) 186 Type Relays

4.03 Satisfactory operation of this relay on alternating current is based on mechanical means. For this reason, the relay is equipped with a light armature, pivoted in the side of the U shaped relay frame which forms the return path for the magnetic circuit. The armature is shaped so that its movement is similar to a circular body on offset centers, resulting in a long swing. The armature engages with a pair of very light feather contact springs before coming to rest on the underside of the core. Although light in weight, the armature does not vibrate sufficiently to open the contacts, because its restoring force, due to its light weight and the use of feather contact springs, is small. See Fig. 52.

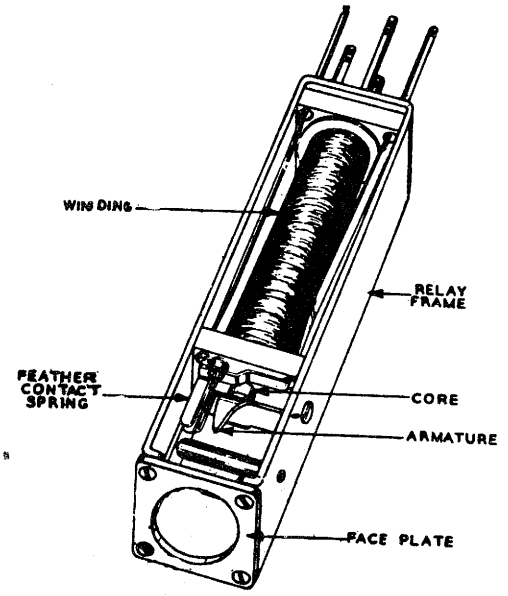

Fig. 52 - 186 Type Relay

(C) 196 Type Relays

4.04 The relay shown in Fig. 53 is known as the 196 type. It is equipped with a U shaped laminated square core and uses form wound coils. The armature is very light and is attached to a return pole piece by means of a thin steel reed. An adjusting screw, which presses against the lower free end of the steel reed, regulates the tension of the armature against the back contact screw. The armature and back contact screw assembly is supported by two armature supporting brackets secured to the upper and lower cores. The relay is also provided with a front contact or stop screw, attached to the armature supporting bracket but not in contact with it.

4.05 The operate and release current flow requirements and the resistance requirements in artificial line networks are met by an adjustment of the armature tension screw and the back and front contact or stop screws. Relays of 196 type are high impedance relays. They are used mainly as ringing relays in high impedance toll cord circuits.

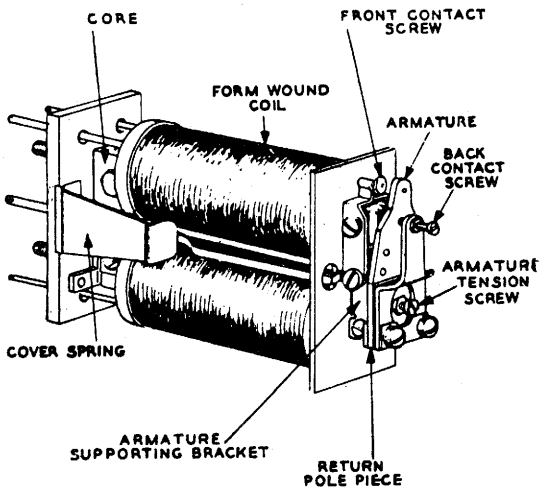

Fig. 53 - 196 Type Relays

(D) J Type Relays

4.06 As previously explained, the alternating current in passing through the winding of the relay creates in the armature a tendency to follow the impulses of the current; that is, operate on the positive and negative peaks and release on the zero points of the wave. To obtain continuous operation it is, therefore, necessary to prevent the armature from releasing at the zero points of the wave. On J type relays this is accomplished by setting up an additional flux which is out of phase with the main flux and is of sufficient strength to hold the armature operated.

4.07 For this purpose, the J type relay, which is similar in construction to the B type, is provided with a forked pole piece and a nickel plated copper adjusting plate. Another copper plate, also nickel plated and of the same size as the front spoolhead, is riveted to the rear of the adjusting plate. Fig. 54 shows a J type relay with the cover and cover spring removed. It will be noted that the two copper plates entirely surround the upper leg of the forked pole piece, but are slotted just below

the lower leg. The object of these copper pieces is to act as a short circuited winding of a single turn over the upper leg, in a local magnetic circuit consisting of the upper leg, armature, lower leg, and core. When the winding of a J type relay is energized, a secondary flux is set up by the short circuited winding which is out of phase with the main flux (see Fig. 55). Although small, this flux is sufficient to prevent the armature from releasing at the zero points of the alternating current wave.

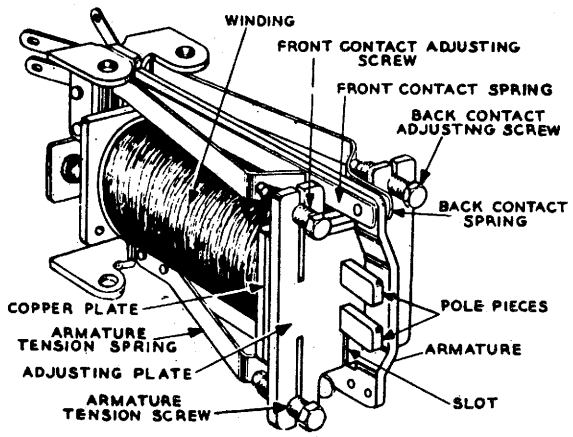

Fig. 54 - J Type Relay

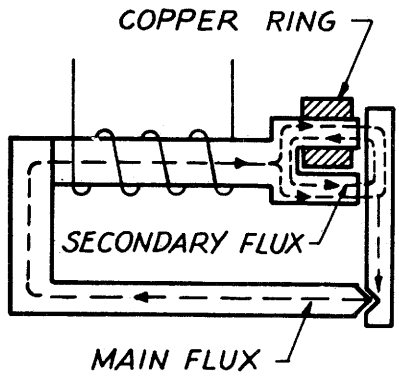

Fig. 55 - Flux Diagram of J Type Relay

4.08 A weighted contact spring is used on some J type relays and when so equipped, the relay is called a "Pendulum" J type relay. See Fig. 56. The purpose of this weighted contact spring is to prevent the relay from operating on momentary surges of current. The pendulum contact spring vibrates for a brief period of time before making continuous contact with the contact on the armature. This delay in contact closure is sufficient to prevent a lock-up of the relay on momentary surges of current on its locking winding which is in series with the pendulum contact.

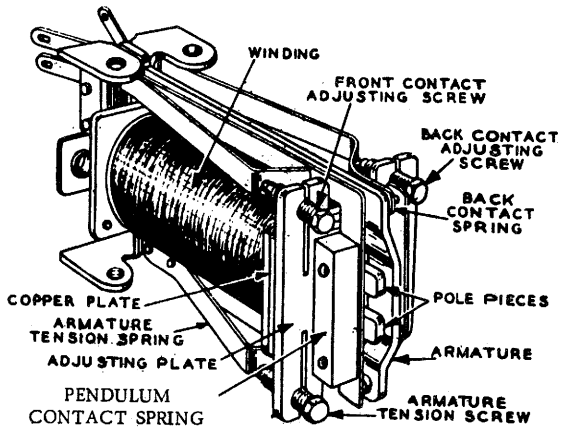

Fig. 56 - Pendulum J Type Relay

4.09 J type relays are equipped with a removable dustproof cover and cover cap. The cover spring, attached to the bottom of the relay structure and supporting the cover, is similar to a shell, partly surrounding the relay. This arrangement is intended to prevent possible changes in the alignment of core and armature when the cover is removed, because correct alignment of these parts is essential for satisfactory operation.

4.10 The J type relays are adjusted by means of the adjusting screws in the adjusting plate, the two upper screws being used to regulate the position of the front and back contact springs or stop springs, while the lower screw is used to regulate the armature tension.